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OPEN PNEUMONOLYSIS—ITS VALUE AND LIMITATIONS

A REVIEW OF THIRTY-SIX OPERATED CASES

T. BRUCE, M.D., AND C. CRAFOORD, M.D.
STOCKHOLM, SWEDEN

OPEN intrapleural pneumonolysis is an old procedure. As early as 1908 Friedrich performed the first operation of this kind. The result, however, was not very encouraging. When division of adhesions was attempted, cavity rupture occurred, and the patient died shortly afterward. In Sweden, open pneumonolysis was first performed by Key, in cooperation with Jacobaeus, in 1915. To obtain sufficient working space, two ribs were resected and the lung was then freed extrapleurally, a procedure which was later recommended by many surgeons. Open pneumonolysis, however, never obtained general favor. Poor results, chiefly attributable to complicating specific and nonspecific empyemas, accentuated the lack of enthusiasm. Moreover, the field of indications became more sharply circumscribed by the introduction of Jacobaeus' closed intrapleural pneumonolysis operation, and by the development of thoracoplasty technique. According to Kremer, only 100 open, as compared to 5,000 closed pneumonolyses, were performed before 1938.

In America, meanwhile, there were advocates of the open method. It even happened that open pneumonolysis completely supplanted the closed procedure. Certainly Alexander, in Ann Arbor, who is a pioneer in this field, stated in 1925 that "thoracoplasty is preferable to pneumothorax which must be preceded by so risky an operation as open intrapleural pneumonolysis." But further experience led him, in 1937, to express some degree of alteration in his views. He said then, "developments in the technique of open intrapleural pneumonolysis have made the operation a valuable one for a small group of patients." In the same year, Alexander reported a series of his own, comprising twenty-nine cases, and reviewed the experiences of certain other American surgeons.

When extrapleural pneumothorax was thereafter introduced as a therapeutic measure, communication with the pleural cavity sometimes arose when pneumonolysis was carried out. The collapse thus obtained is designated "pneumothorax mixte." This gave to many workers an increased comprehension of how the pleura in tuberculosis reacts when it is extensively opened. As regards

From Söderby Hospital for Tuberculosis, Uttran, Stockholm.

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collapse, no fundamental difference is implied if, on inducing extrapleural pneumothorax, free communication with the pleural cavity is obtained, or if the pleura is first opened and the lung thereafter freed extrapleurally, which is what commonly happens. Holst stated also in 1946: "If one wishes to enter the extrapleural space directly as in extrapleural pneumothorax or transpleurally through a free pleural cavity is a question of choice of technical method in each individual case."

The early 1940's saw a reawakening in Sweden of the dormant interest in open pneumonolysis. The operation was taken up by one of the writers (Crafoord) in cooperation with various other phthisiologists (Dahlstedt, Gullbring, Westergren) and by Hultén in cooperation with Hedvall. In 1947 Crafoord reported fifty-five, and Hultén seventy-three operated cases. Hedvall spoke in 1946 of "wide-open" pneumonolysis as a new surgical method in tuberculosis therapy. Hulten stated at the same time: "Aftercare is of fundamental importance, and there apply the innovations which we have reported." Modern postoperative treatment of the pleural cavity with penicillin has certainly reduced the risk of secondary infection formerly so dreaded in these patients. Such enthusiasm for, and wide experience of open pneumonolysis as that of Hedvall and Hultén are probably not to be found elsewhere is this country; but Swedish phthisiologists and surgeons now recognize the procedure, and employ it sometimes in cases which might otherwise have been considered for closed division of adhesions or thoracoplasty.

PERSONAL INVESTIGATIONS

The following is a report of our joint series of thirty-six patients treated with open intrapleural pneumonolysis. One of us (Crafoord) has, in cooperation with other phthisiologists, performed the operation on a further forty patients up to 1949. *To open pneumonolysis have been referred cases where (a) closed division of adhesions might possibly have been considered but found inadvisable, (b) artificial pneumothorax would otherwise have been terminated in favor of thoracoplasty* or, in a few instances, extrapleural pneumothorax.

The distribution of the clinical material over calendar years is:

year	1943	1944	1945	1946	1947	1948	1949
Number of cases	1	1	14	8	4	4	4

It is seen that the majority of the operations were performed in 1945 and 1946, the years following Hedvall's and Hultén's report on their preliminary results. It may, even at this point, be mentioned, and should be in the nature of things, that indications change as experience of the method increases. For this reason our series has fewer patients after 1947. As final results after voluntary cessation of pneumothorax therapy can be presented only for those patients whose operations were performed up to and including 1946, *the material has been divided into two main groups. Group A comprises the period 1943-1946 and consists of twenty-four patients. Group B includes 1947-1949, and has only twelve patients.*

The most important clinical details of each patients are reported in Table I.

Group A (1943-1946).—

The twenty-four patients in this group are most conveniently divided into (1) those with *cord-type adhesions*, where open pneumonolysis was carried out instead of the closed procedure, and (2) patients with *direct fusion of the* visceral and parietal *pleurae*, where open pneumonolysis was substituted for thoracoplasty (or possibly extrapleural pneumothorax). The former subgroup contains four and the latter twenty patients. Open pneumonolysis in both these adhesion types is discussed below.

Cord-type Adhesions.—In the group of four cases where open pneumonolysis was substituted for closed, short, thick cords attached to the chest wall held pulmonary cavities distended. Cavity diameters did not exceed 3 cm. All these patients were sputum positive before operation. Rapid postoperative cavity closure was obtained in all four cases, and therapeutic pneumothorax could be successfully maintained. Serous effusion occurred in only one case, and was reabsorbed spontaneously. When air refills were discontinued, clinical cavity closure was present in all cases. In three patients the treated lung showed only insignificant failure to re-expand; in the fourth there was conspicuous ipsilateral inexpansibility with fixation of the diaphragm. As this is not infrequently a sequel to pneumothorax therapy where open pneumonolysis has not been carried out, the *final results* must be regarded as *satisfactory*.

Direct Fusion of the Pleurae.—Preoperative period: In twelve of the twenty cases where open pneumonolysis was substituted for thoracoplasty (or possibly extrapleural pneumothorax) the untreated lung was healthy. Of the remaining eight patients in this group, two had simultaneous contralateral pneumothorax; a further two had reduced contralateral capacity following concluded pneumothorax and thoracoplasty, respectively. The untreated lung presented concomitant lesions, relatively insignificant in extent in three patients, and in one, cavernous tuberculosis.

In all twenty patients, there was cavernous tuberculosis of the pneumonolysis-treated lung. The respective diameters of cavities were approximately 1 cm. in five patients, 2 cm. in four, 3 cm. in six, and 4 cm. in five cases. With only one exception the entire series was sputum positive on direct smears prior to pneumothorax induction. Seventeen patients were still sputum positive at the time of open pneumonolysis.

More or less extensive closed division of adhesions had already been carried out in seven cases; thirteen were thus referred to open pneumonolysis directly or after thoracoscopy. Pleural effusion was present preoperatively in seven patients; in six of these the exudate was serous, although *M. tuberculosis* could be cultured. One patient had tuberculous empyema.

Operation: Direct symphysis was chiefly localized to the pleurae in the region of the cupola and the mediastinal surface, and varied in extent; but in most cases the area freed was at least as large as the palm of the hand. Sometimes the adhesion was loose but as a rule stripping was undertaken extrapleurally in thickened, sometimes particularly dense tissue. The process of stripping was often associated with considerable difficulty.

TABLE I

CASE NO.	SEX	AGE	PREOPERATIVE PERIOD					
			RIGHT LUNG	LEFT LUNG	SPUTUM	PNEUMOTHORAX INDUCED	THORACOSCOPY; CLOSED PNEUMONOLYSIS	EFFUSION
1	Female	28	Ap.–I_2. Cav. 2 cm. I_2.	Nothing abnormal	Pos.	12- 2-43	Partial cl. pnml.	—
2	Female	38	Cav. 1 cm. I_2.	Pnth. 33-40.	Pos.	7- 5-43	—	June, '44; Empyema, Oct. 44
3	Male	24	Upper lobe. Cav. 3 cm. I_1.	Nothing abnormal	Pos.	30-11-44	—	Serous Jan., '45
4	Male	37	Upper lobe. Cav. 4 cm. I_2.	Nothing abnormal	Pos.	7-10-44	Thscpy. 0 cl. pnml.	—
5	Male	47	Upper lobe. Cav. Ap.–I_2, max. 4 cm.	Insignificant I_{2-4}.	Pos.	10- 1-45	Thscpy. 0 cl. pnml.	—
6	Male	32	Nothing abnormal	Ap.–I_1. Cav. 2 cm. Ap.	Pos.	13- 2-45	Thscpy. 0 cl. pnml.	—
7	Male	31	Nothing abnormal	Ap.–I_2. Cav. 2 cm. I_1.	Pos.	25-10-44	Thscpy. 0 cl. pnml.	—
8	Female	25	Ap.–I_1. Cav. 3 cm. Ap.	Nothing abnormal	Neg.	29- 4-45	Thscpy. 0 cl. pnml.	Serous June, '45
9	Female	25	Upper lobe. Cav.I_{1-2}. max. 3 cm.	Nothing abnormal	Pos.	10- 3-44	Partial cl. pnml.	—
10	Female	43	Ap.–I_2. Cav. 3 cm. I_1.	Nothing abnormal	Pos.	16-10-44	Partial cl. pnml.	—
11	Male	25	Ap.–I_2. Cav. 2 cm. Ap.	Apical thoracoplasty '42	Pos.	16- 6-45	Partial cl. pnml.	—
12	Male	20	Pnth. since April '43.	Upper lobe. Cav. Ap.–I_1, max. 4 cm.	Pos.	11- 6-45	Partial cl. pnml.	—
13	Male	52	Nothing abnormal	Ap.–I_3. Cav. 2 cm. I_1.	Pos.	11- 8-45	Partial cl. pnml.	—
14	Female	34	Ap.–I_1. Cav. 2 cm. I_1.	Nothing abnormal	Pos.	3- 4-45	Partial cl. pnml.	Serous July, '45
15	Female	33	Nothing abnormal	Ap.–I_2. Cav. 1 cm. I_1.	Pos.	1- 9-45	Thscpy. 0 cl. pnml.	Serous Oct., '45
16	Female	33	I_{1-2}. Cav. 1 cm. I_1.	Nothing abnormal	Pos.	2- 7-45	—	Serous July, '45
17	Male	22	Nothing abnormal	Upper lobe. Cav. 2 cm. I_1.	Pos.	5- 9-45	Thscpy. 0 cl. pnml.	—
18	Female	28	Upper lobe. Cav. 3 cm. I_1.	Small cav. Ap. lower lobe	Pos.	25-10-45	Partial cl. pnml.	—

OPERATION		POSTOPERATIVE PERIOD			FINAL RESULTS		
DATE	EXTENT	IMMEDIATE COMPLICATIONS	EFFUSION, EMPYEMA	CAVITY CLOSURE	PNEUMOTHORAX TERMINATED	CAVITY HEALING	PULMONARY INEXPANSIBILITY
15/ 7/43	Index-finger-thick cord, some mm. long.	—	—	Yes	1945	Yes	Insignificant
14/11/44	Direct pleural fusions 4 cm.	—	Empyema, see PREOPERATIVE PERIOD	Yes	1947	Yes	Extreme
13/ 2/45	Extensive direct fusion.	—	Empyema Sept., '45. Oleothorax	Yes	See EFFUSION, EMPYEMA	Yes	Moderate
20/ 3/45	Direct medial pleural fusion: Ap.-Hilus.	—	Serous effusion	Yes	1948	Yes	Extreme
7/ 4/45	Extensive coarse direct pleural fusion.	—	Serous effusion	No	Bilateral cavities. Died, 47	—	—
17/ 4/45	Direct pleural fusions mediastinally.	—	Serous effusion. Empyema, '46.	Yes	1949	Yes	Extreme
25/ 4/45	Finger-thick short cord.	—	—	Yes	1949	Yes	Insignificant
10/ 7/45	Direct fusion, the size of a child's palm.	—	Effusion, see PREOPERATIVE PERIOD. No empyema.	Yes	1950	Yes	Extreme
1/ 8/45	Direct fusion, the size of a child's palm.	—	Serous effusion. Empyema, '46.	Yes	1948	Yes	Moderate
13/ 9/45	Finger-thick cord, some mm. long.	—	—	Yes	1949	Yes	Moderate
13/10/45	Direct pleural fusions mediast. Ap.-Hilus (loose).	—	Serous effusion, insignificant.	Yes	1948	Yes	Moderate
23/10/45	Direct pleural fusions 4 cm.	Cav. perf. 18-11-45. Mixed-infect.. Empyema. Died 10-12-45	—	—	—	—	—
3/11/45	Direct pleural fusions 5 cm.	—	Serous effusion, insignificant.	Yes	1949	Yes	Insignificant
10/11/45	Direct thick fusion, the size of a child's palm	—	Effusion, see PREOPERATIVE PERIOD. Empyema, '46.	Yes	1949	Yes	Moderate
6/12/45	Extensive direct pleural fusions, the largest the size of the palm.	—	Effusion, see PREOPERATIVE PERIOD. No empyema.	Yes	1949	Yes	Extreme
17/12/45	Extensive direct pleural fusions.	—	—	Yes	1950	Yes	Extreme
16/ 2/46	Short cords.	—	Serous effusion, insignificant.	Yes	1950	Yes	Insignificant
23/ 2/46	Extensive firm direct fusions.	Mil. tub. Died 25-3-46	—	—	—	—	—

TABLE 1

CASE NO.	SEX	AGE	PREOPERATIVE PERIOD					
			RIGHT LUNG	LEFT LUNG	SPUTUM	PNEUMOTHORAX INDUCED	THORACOSCOPY: CLOSED PNEUMONOLYSIS	EFFUSION
19	Male	25	Nothing abnormal	Ap.–I_1. Cav. 1 cm. I_1.	Pos.	17- 1-46	—	—
20	Male	21	I_{1-3}. Cav. 1 cm. I_1.	Pnth. since Sept. '42.	Pos.	5- 9-44 (no adhesions)	Thscpy. 6-3-46. Dir. pl. fus. upper lobe.	—
21	Male	54	Ap.–I_3. Cav. 3 cm. I_1.	Ap.–I_2. No cav.	Pos.	15- 6-46	Sput. pos. 0 thscpy. Cl. pnml.	—
22	Female	45	Ap.–I_2. No cav.	Ap.–I_3. Cav. 4 cm. I_1.	Pos.	29- 1-46	Thscpy. 0 cl. pnml.	—
23	Male	31	Upper lobe. Cav. 3 cm. Ap.	Nothing abnormal	Pos.	15- 8-46	Partial cl. pnml.	Serous Sept., '46
24	Male	46	Ap.–I_4. Cav. Ap.–I_2, max. 3 cm.	Nothing abnormal	Pos.	15- 8-46	Thscpy. 0 cl. pnml.	—
25	Female	33	Upper lobe. Cav. 3 cm. Ap.	Nothing abnormal	Pos.	31- 7-46	Partial cl. pnml.	—
26	Female	38	Upper lobe. Cav. 3 cm. I_1.	Nothing abnormal	Pos.	11- 3-47	Partial cl. pnml.	Serous Apr., '47
27	Female	40	Upper lobe. Cav. 3 cm. I_1.	Nothing abnormal	Pos.	8- 5-47	Partial cl. pnml.	Serous May, '47
28	Female	27	Ap.–I_2. No cav.	Upper lobe. Cav. 3 cm. I_1.	Pos.	3- 3-47	Partial cl. pnml.	—
29	Male	32	Upper lobe. Cav. 4 cm. I_1.	Nothing abnormal	Pos.	11-10-47	Thscpy. 0 cl. pnml.	—
30	Male	46	Nothing abnormal	Upper lobe. Cav. 2 cm. I_1.	Pos.	27-10-47	Partial cl. pnml.	—
31	Male	24	Nothing abnormal	Ap.–I_3. Cav. I_{1-2}, max. 4 cm.	Pos.	10- 6-48	Thscpy. 0 cl. pnml.	Serous July, '48
32	Male	37	Upper lobe. Cav. 4 cm. I_1.	Insignificant I_{3-4}.	Pos.	18- 8-48	Thscpy. 0 cl. pnml.	—
33	Female	31	I_{1-2}. No cav.	I_{2-3}. Cav. I_{2-4}, max. 3 cm.	Pos.	18- 8-48	Thscpy. 0 cl. pnml.	—
34	Male	38	Nothing abnormal	Ap.–I_2. Cav. 3 cm. I_2.	Pos.	11- 3-49	Partial cl. pnml.	—
35	Male	32	Nothing abnormal	Ap.–I_4. Cav. 4 cm. Ap.	Pos.	1- 6-49	Partial cl. pnml.	—
36	Male	36	Nothing abnormal	Upper lobe. Cav. 2 cm. I_1.	Pos.	5- 7-49	Partial cl. pnml.	—

Cont'd

OPERATION		POSTOPERATIVE PERIOD			FINAL RESULTS		
DATE	EXTENT	IMMEDIATE COMPLICATIONS	EFFUSION, EMPYEMA	CAVITY CLOSURE	PNEUMOTHORAX TERMINATED	CAVITY HEALING	PULMONARY INEXPANSIBILITY
23/ 3/46	Direct pleural fusions Ap.; The adherent lower lobe was not freed	—	Serous effusion, insignificant.	Yes	1949	Yes	Insignificant
13/ 4/46	Extensive. Loose direct pleural fusions.	May, '46, progress left lung	Serous effusion, April, '46.	Yes	See IMMEDIATE COMPLICATIONS. Died 26-10-46	—	—
13/ 7/46	Palm-size, firm direct pleural fusion.	—	Serous effusion. Empyema, 47.	Yes	1950	Yes	Moderate
23/ 7/46	Extensive coarse direct pleural fusions.	—	Serous effusion.	Yes	1949	Yes	Extreme
25/10/46	Palm-size, coarse direct pleural fusion.	—	Effusion, see PREOPERATIVE PERIOD. No Empyema.	Yes	1950	Yes	Extreme
12/11/46	Extensive coarse direct pleural fusions.	Hemothorax + mediast. emphysema. Died 14-11-46	—	—	—	—	—
15/ 3/47	Finger-thick cord, some mm. long.	—	—	Yes	—	—	—
18/ 6/47	Palm-size, direct pleural fusion.	—	Effusion, see PREOPERATIVE PERIOD. Empyema, '47.	Yes	—	—	—
18/ 6/47	Little-finger thick, short cord.	—	Effusion, see PREOPERATIVE PERIOD. Empyema, '47.	Bronch-pl. fistula, '50	—	—	—
5/ 7/47	Direct pleural fusion 4 cm.	—	Serous effusion, insignificant.	No. Progr. right l. cav., '48	—	—	—
6/ 2/48	Extensive coarse direct pleural fusions.	—	Serous effusion. Empyema, '48.	Yes	—	—	—
17/ 4/48	Extensive coarse direct pleural fusions.	Evac. of clots + decortication 27-4-48	Serous effusion.	Yes	—	—	—
7/ 8/48	Direct pleural fusion 4 cm.	—	Effusion, see PREOPERATIVE PERIOD. Empyema, Jan. '49.	Yes	—	—	—
4/12/48	Direct pleural fusion 5 cm.	—	Serous effusion	Yes	—	—	—
30/ 4/49	Extensive direct pleural fusions.	—	Serous effusion	Yes	—	—	—
14/ 5/49	Palm-size, firm direct pleural fusion.	—	Effusion, insignificant	Yes	—	—	—
25/ 7/49	Short cords.	—	Effusion, insignificant	Yes	—	—	—
1/10/49	Finger-thick cord, some mm. long.	—	Effusion, insignificant	Yes	—	—	—

Postoperative period: Three patients died shortly after surgery. In one of these, death occurred after two days as a result of hemothorax and mediastinal emphysema; the second patient became suddenly very ill three weeks after operation, and died after a further three weeks from mixed-infection empyema, which was a sequel to extensive cavity perforation; there was marked postoperative deterioriation in the condition of the third patient, who died one month later from miliary tuberculosis.

Pleural effusion was present at the time of operation in seven of the remaining seventeen patients in this group. There was no reaccumulation of fluid in one case, but in the others effusion continued. Tuberculous empyema developed in 3 instances, exclusive of the case where purulent effusion was present preoperatively. In seven of the other ten patients there were large postoperative accumulations of fluid, which developed into empyema in three cases. The remaining three patients had only insignificant effusions which reabsorbed spontaneously. Persistent effusion was treated with repeated aspiration, and in two cases empyematous fluid was partly replaced by oil. Effusion finally ceased in some cases; in others, the effusion formed a covering layer at the conclusion of pneumothorax therapy. In none of these cases was there secondary pyogenic infection of the pleural cavity.

Cavity closure was obtained in sixteen patients. Bronchial tuberculosis developed in the later course of the disease in one case; both lungs were affected preoperatively in this patient, and bilateral cavernous phthisis was present at death. In another case, despite ipsilateral cavity closure, death occurred six months after surgery from hemoptysis which originated in the contralateral lesions. Thus five patients in all died during the pneumothorax period.

Final Results.—At the conclusion of pneumothorax therapy, this group consisted of fifteen patients. As far as can be judged, clinical healing of the tuberculous pulmonary process took place in all cases. Similarly satisfactory results cannot, however, be recorded from the functional aspect. The effusions caused pleural thickening with diaphragm fixation and pulmonary inexpansibility. In three patients, the treated lung must be regarded as functionally useless and incapable of re-expansion; preoperative empyema was present in one of these cases. The lung is still capable of aeration in another five cases, but pleural thickening is so extensive and reduction of diaphragmatic mobility so marked that the remaining function can scarcely be allotted practical importance. Yet another five patients have more moderate pulmonary inexpansibility, but such restriction of diaphragmatic movement that ventilation capacity is certainly gravely impaired. Finally, the expansile powers of the lung are only slightly reduced and diaphragmatic mobility insignificantly affected in two cases.

Conclusions from Group A.—The account of the above series of open pneumonolysis in pneumothorax with direct fusion of the pleurae shows a not insignificant primary mortality; pleural complications, lengthy and difficult to treat, cause considerable reduction of functioning parenchyma even when satisfactory healing of lesions is obtained. When these facts became apparent, we attempted a re-evaluation of the advisability of open pneumonolysis. We have also judged afresh in retrospect the situation in the twenty reported cases at

the time of operation. In the light of experience gained, we have reconsidered whether open pneumonolysis should have been substituted for thoracoplasty. It may be pertinent to state first that two patients who declined the thoracoplasty originally advised, underwent open pneumonolysis instead; both these patients, who had pleural effusion at the time of operation, belong, of course, a priori, to the thoracoplasty group. For eight patients who had lesions of a type and extent which promised adequate collapse with a minor or moderately large thoracoplasty, this should have been the operation of choice. In six cases where subtotal or total thoracoplasty was necessary for satisfactory collapse, the choice of surgery was more difficult. The several stages of thoracoplasty constituted a disadvantage in this group, although even this did not perhaps fully outweigh the greater risk of open pneumonolysis. Other arguments for and against both procedures could certainly be presented here and the final choice of method may involve a careful analysis of all the relevant factors. Open pneumonolysis was, even in retrospect, the most suitable intervention for two patients. In one of these, local direct pleural symphysis had occurred under effective pneumothorax therapy, but was estimated to be fairly loose. In the other, the intention was to free only the diseased upper lobe, not the unaffected lower lobe which was extensively adherent; the intervention here was thus designed to produce collapse similar to that in extrapleural pneumothorax, with good diaphragmatic mobility. Finally, the general condition of two patients was so poor that the decision as to active collapse therapy should have been postponed; thoracoplasty might conceivably have been contemplated later but open pneumonolysis, which at first appeared justifiable was not, in the light of present experience, to be recommended.

It is apparent from the above discussion that, when the question of the most suitable collapse measures for the twenty reported pneumothorax patients with direct pleural fusion is reviewed against the background of our present experience, open pneumonolysis could have been advised for at most eight patients.

Group B (1947-1949).—

As experience of open pneumonolysis was gained, indications were applied more cautiously. Even if knowledge of the operation was as yet incomplete, the extent of its practice was decreased after 1947. Thus, no more than twelve patients were submitted to the procedure from 1947-1949 inclusive (see Table I). The period of pneumothorax is nearing conclusion in the autumn of 1950 only in the earliest operated of these patients. Final results cannot, therefore, be presented, but the more immediate sequellae to surgery may be surveyed.

Distribution of this group analogous to that of group A shows that four patients underwent open instead of closed pneumonolysis. Open pneumonolysis was substituted for thoracoplasty in eight cases.

Cord-type Adhesions.—All four patients upon whom open instead of closed pneumonolysis was performed were sputum positive at operation and had patent cavities. The diameters of cavities did not exceed 4 cm. The postoperative course was uneventful in three patients. In the fourth case, a short adhesion,

as thick as the little finger, was freed; this patient (who had active pleurisy at the time of surgery) developed tuberculous empyema postoperatively, and finally bronchial fistula.

Direct Fusion of the Pleurae.—Three of the eight patients who had open pneumonolysis as an alternative to thoracoplasty had contralateral lesions; these were, at least at the time of operation, estimated to be quiescent. All eight patients had cavernous tuberculosis in the treated lung. Cavity diameters were approximately 2 cm. in one case, 3 cm. in four, and 4 cm. in three cases. All patients were sputum positive both when pneumothorax was induced and when pneumonolysis was performed. Each patient had been examined by thoracoscopy, and four had undergone preliminary closed pneumonolysis. Clear, serous effusion was present in two patients at operation.

Direct pleural fusion in these eight cases was, on the average, less extensive than in the A group. In three patients, however, extensive stripping was carried out; but in another three the surface stripped was no more than five cm. in diameter.

There were no deaths in this group, either in association with operation or up to the present (summer, 1950). One patient had such a severe hemothorax that evacuation of coagulate and pulmonary decortication was necessary about a week after pneumonolysis. Cavity closure was obtained in all cases but one; in this patient, ipsilateral pneumothorax was abandoned because of progression of contralateral lesions. In association with operation five patients developed persistent pleural effusion; three of these were tuberculous empyemas. Both the patients who already had an effusion at the time of surgery developed empyema postoperatively yet in one of these the area freed was not extensive. In no case was there secondary pyogenic infection of the pleural cavity.

Although pneumothorax therapy still proceeds in these eight cases, it is already manifest that in five of them pumonary function has been gravely impaired by the operation and its sequellae. For three of these patients the alternative was, however, total thoracoplasty. In the three remaining cases, such pulmonary inexpansibility, as is apparent up to the present, is very moderate.

On the basis of our present experience of open pneumonolysis in pneumothorax with direct fusion of the visceral and parietal pleurae, we may summarize thus: although this operation was employed over the period 1947-1949 on a much smaller scale than formerly, the alternative intervention—thoracoplasty—was, in our opinion, nevertheless preferable for at least two or three patients.

DISCUSSION

The results of surgical collapse measures in pulmonary tuberculosis are often difficult to judge. Many factors are involved here, the chief being perhaps the tendency of the disease to develop fresh lesions later in its course. If the original plan of treatment cannot, in consequence hereof, be consistently adhered to, it does not follow that the treatment performed was unsuitable. As a rule, the choice of therapy is not difficult. When several methods are available, the

selection may, however, be far from easy, especally as complications often appear to arise capriciously in the different interventions, and are unpredictable in the individual case.

Open pneumonolysis has regained current interest as a surgical adjunct to pneumothorax, and may be discussed along with other methods, because altered circumstances have decreased the risks associated with the operation. Hultén has, as mentioned, stressed the importance of sound aftercare; in our series, also, penicillin treatment of the pleural cavity has been valuable as prophylaxis against the mixed-infection empyema, formerly so dreaded. Empyema of this type occurred in our material only in the case where cavity rupture took place some time after operation.

It is, however, open to discussion, if the increased therapeutic resources we now command warrant that open pneumonolysis be accorded equality with, or precedence over, certain other collapse-promoting measures. During recent years, our therapeutic arsenal has gained antibiotic and chemotherapeutic preparations of great antituberculosis value; these, when surgical interventions are planned, are extremely helpful in preoperatively stabilizing and postoperatively controlling the disease. The pleural complications of open pneumonolysis can thus also be favorably affected. But despite therapeutic advances, we still await a substance which is capable of preventing and curing tuberculous empyema. When that goal is reached, the time will have come for a fresh appraisal of open pneumonolysis in competition with other collapse measures. For the present, at least, we must reckon with pleural complications in association with open pneumonolysis.

In discussing the therapeutic value of open pneumonolysis in the surgical treatment of pulmonary tuberculosis, it would appear to be most appropriate, in conformity with the cases presented above, to differentiate thus: on the one hand, open pneumonolysis as a substitute for closed division of adhesions, and on the other, as an alternative to other forms of collapse, particularly thoracoplasty.

In *short, cord-type adhesions,* closed pneumonolysis not infrequently carries manifest danger of pulmonary trauma or hemorrhage. If open pneumonolysis is performed instead, these risks are reduced or eliminated. The advantages this implies more than outweigh the risk of postoperative effusion, which hazard, in open division of cord-type adhesions, should not be greater than if the closed procedure had been employed. *As a substitute for closed pneumonolysis* in this type of case, we consider that *open pneumonolysis well merits use,* perhaps even on a greater scale than at present.

Formerly, when the effect of pneumothorax was nullified by direct fusion of the visceral and parietal pleurae, treatment was almost always discontinued in favor of other collapse measures, chiefly thoracoplasty. The idea of obtaining satisfactory collapse and conditions for continued pneumothorax by separating directly fused pleurae is attractive. On cursory contemplation, *open pneumonolysis* should be preferable to a mutilating thoracoplasty. However, the

potential risks and results of both methods are of fundamental significance in the choice of surgery. There is, consequently, reason for making *a comparison of the alternatives.*

Thoracoplasty now carries comparatively small immediate risks. The atelectases which sometimes occur as early operative sequellae, clear spontaneously or respond to treatment. Pleural complications, which are chiefly associated with the opening of a free pleura, are rare. In other respects, also, the postoperative course is generally uneventful, and the ultimate results good as regards cavity healing. Some limitation of function, in degree dependent upon the scope of the thoracoplasty, naturally results, but, provided the operation is moderate in extent, diaphragmatic mobility is not affected. Not until subtotal or total thoracoplasty has been carried out is the function of the lung largely or completely lost.

In open division of directly fused pleurae, cavity perforation and hemorrhage into the pleural cavity may occur with grave immediate consequences. Moreover, tuberculous granulation tissue may be present over the entire operation field; for this reason, the possibilities of spread of the disease via lymphatic or blood vessels or by direct contact must be kept in mind. The pleurisy which occurs so often in the later course of the disease is certainly, in many cases, a sign that tuberculous lesions were opened. Pleural complications often cause lengthy invalidism and reduce the patient's strength. This applies particularly to tuberculous empyema, which occurred in about every third patient in our series. Pleural thickening with fixation of the diaphragm and pulmonary inexpansibility are the usual sequellae of pleural complications. The final result when pneumothorax is terminated is often a considerable loss of function, out of reasonable proportion to the degree of collapse necessitated by the disease, particularly the cavity, for healing.

Comparison of the operations indicates, in our experience, that thoracoplasty contains essentially less immediate risk, and has a considerably smoother postoperative course than open pneumonolysis. As regards cavity healing, good results are obtained by both methods. In those cases of pneumothorax with direct pleural fusion, where thoracoplasty and open pneumonolysis are alternative possibilities for the attainment of the desired collapse, we believe that, with regard to risks and results, thoracoplasty should receive primary consideration. Open pneumonolysis cannot, therefore, be accorded the same recommendation for direct fusion of the pleurae as for certain types of cord adhesions.

This view is in complete conformity with the opinion expressed by Alexander in 1937, that in the absence of contraindications, thoracoplasty is preferable as its surgical risks and postoperative complications are less than those of open pneumonolysis. We would add here, to the further advantage of thoracoplasty that, as regards impairment of function after completed therapy, the results obtained by this procedure are often substantially better than those of open pneumonolysis.

We agree with Alexander that open pneumonolysis has its justification as a method of treatment in pneumothorax with direct fusion of the pleurae, but that indications must be sharply defined. To attempt a statement of guid-

ing principles for the employment of the operation is naturally very difficult, and opinions unavoidably diverge. Certain general aspects, however, may be worthy of observation. It is important that the patient, to whom the prospect of continued pneumothorax refills after pneumonolysis, may be misleadingly attractive, should be fully informed of the risks attached to the alternative measures; his subjective attitude may otherwise exercise a distorting influence on the choice of surgery. It should also be emphasized that thoracoscopy yields valuable information as to the extent and degree of the proposed operation, and may thus assist the choice in difficult cases. The general rule certainly is that the more extensive the direct pleural fusion, the greater the likelihood of postoperative complications. But even the freeing of very limited areas may give rise to pleurisy reaction and empyema. The risk of empyema appears to be particularly great if active pleurisy is present at the time of operation. Hedvall and Hultén also advise against open pneumonolysis in pleurisy cases.

In the majority of patients with extensive direct fusion of visceral and parietal pleurae, it is probably advisable to refrain from open pneumonolysis and to abandon the pneumothorax. Particularly if the type and localization of the pulmonary lesions are such that only limited thoracoplasty is required, that operation is decidedly to be preferred, not least with regard to the desirability of retaining as much as possible of the pulmonary function. Should total thoracoplasty be necessary for adequate collapse, open pneumonolysis may, with some degree of justice, be brought up in discussion. The choice of surgery will then be dependent upon the evaluation of the complications associated with the operation. The lung will sustain injury to its function irrespective of which of the two surgical methods is employed. In such borderline cases, it is the doctor's familiarity with, and estimation of the different interventions, which finally decide the method to be employed.

Under special circumstances which, however, have more the character of exceptional cases, *open pneumonolysis may be directly advisable,* e.g., when there is good reason to believe that the adhesions are loose, or when retention of function in the basal parts of the lung may be anticipated, as adhesion with the diaphragm need not be freed.

Even if open pneumonolysis has thus a certain range of indications, we have now accepted this as an established fact: that, in pneumothorax with direct pleural fusion, it can be contemplated for a very limited number of patients, and then only after mature deliberation.

SUMMARY

The writers report a series of thirty-six pneumothorax patients who underwent open pneumonolysis of short, cord-type adhesions or of direct fusion of the visceral and parietal pleurae. The results justify the following evaluation of the method.

In short, cord-type adhesions, where closed pneumonolysis implies manifest risk of pulmonary trauma or hemorrhage, open pneumonolysis is advocated.

In direct fusion of the visceral and parietal pleurae, the value of open pneumonolysis is considerably more limited, due to: (1) the risk of pulmonary trauma during, and hemorrhage closely following the operation, (2) pleural complications, particularly empyema, with their sequellae of pleural thickening, diaphragm fixation and pulmonary inexpansibility. Thoracoplasty, which is usually the alternative measure, is less hazardous, and as cavity closure is generally obtained by both methods, thoracoplasty is preferable in most cases. Apart from certain exceptional cases, open pneumonolysis of direct pleural fusion should only be employed when other conceivable collapse measures are so extensive that the function of the diseased lung will be greatly reduced or possibly lost.

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PULMONARY DECORTICATION IN TUBERCULOSIS

A Report of 22 Cases

J. J. Quinlan, M.D., V. D. Schaffner, M.D., and J. E. Hiltz, M.D.
Kentville, Nova Scotia

PULMONARY decortication involves peeling from the surface of the pleura abnormal fibrinous layers which have formed over it.

The procedure now commonly known as decortication was first performed by Fowler[1] on Oct. 7, 1893, in the treatment of a previously drained chronic empyema of thirty-three months' duration. He removed a mass of scar tissue occupying three-fifths of the right pleural cavity from the thoracic wall, diaphragm, pericardium, and lung. The cavity was packed open with gauze and the lung expanded in twenty-eight days. However, to Delorme must go greater credit for envisioning and rationalizing the operation, although his first case did not come to surgery until January, 1894. It was this surgeon who first used the term decortication, and it is interesting to note that neither Delorme nor the surgeons who made use of the operation in the early years used the term "thickened pleura." Delorme described the pathology of the shell as false membrane encapsulating the lung. There developed very soon, however, the erroneous idea that thickened pleura was removed, and this incorrect conception of the basic pathology has persisted with few exceptions until very recently. In the early years the operation was used most frequently in combination with collapse procedures, especially the Schede thoracoplasty. A complete description of decortication appeared again in 1915 when Lilienthal described his major intercostal thoracotomy and lung mobilization. Lilienthal was the first to treat acute empyema by decortication, and developed his procedure because of dissatisfaction with the high mortality following thoracostomy. His results were quite good, although the mortality, 19 per cent, was high by present-day standards. In the 1920's and 1930's, the operation was performed relatively infrequently, and had practically fallen into disuse until 1946 when a series of papers were presented at the Annual Meeting of the American Association for Thoracic Surgery describing the experiences of American surgeons[2, 3] in the treatment of chronic organizing hemothorax by decortication. At the same meeting, Gurd[4] of Montreal presented three cases of tuberculous empyema which he had treated by decortication. His operation differed from the others in that he removed a portion of the chest wall as in a Schede procedure and the wound was packed open. Mulvihill, in discussing Gurd's[4] paper, presented a case of his own in which, through an intercostal incision, he had removed almost the entire peel encasing the lung and diaphragm in a case of unexpandable lung following pneumothorax therapy. It was felt at that time that the operation would be of little use in the treatment of a frank tuberculous empyema, and

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it was suggested that the empyema should first be sterilized before any attempt was made to decorticate the lung. However, increasingly numerous reports began to appear in the literature of the successful treatment of tuberculous empyema by this process, and it is now considered that pulmonary decortication is a most important procedure in the treatment of one of the most dreaded complications of artificial pneumothorax.

INDICATIONS

The aim of pulmonary decortication is to remove the encasing peel that is preventing the lung from re-expanding. It is therefore indicated in the following instances:

1. Unexpandable lung following artificial pneumothorax therapy
   (a) to obliterate the space,
   (b) to increase vital capacity in order to permit surgery for the other lung,
   (c) to replace displaced mediastinum in the presence of symptoms.
2. As an adjunct to pulmonary resection. Removal of a lobe or lung is made much easier in cases where there is marked symphysis if the plane between visceral pleura and the encasing peel is first found and decortication performed. Also, in cases of lobectomy, if rapid obliteration of the pleural space is to be obtained, as well as maximum function of the remaining lung, decortication of this lobe or lobes must be carried out before the chest is closed.
3. Tuberculous empyema.

ALTERNATIVES TO DECORTICATIONS

In the past, when decortication was not being used in the treatment of these cases, the following measures were carried out:

1. *Continuous aspiration:* This, when successful, produced obliteration of the space by the marked retraction of the mediastinum to meet the chest wall which also was pulled in. This frequently produced symptoms, such as dyspnea and palpitation, and the function of the lung was not improved. Indeed, because of the necessary overexpansion of the contralateral lung, vital capacity was often decreased.

2. *Thoracostomy:* Rib resection and drainage of the chest was often necessary as an emergency, but this procedure alone rarely effected obliteration of the residual space.

3. *Thoracoplasty:* An extensive thoracoplasty was successful in obliterating the space in a considerable proportion of these cases, although when one notes the nature of the peel at operation one wonders how it ever could have been collapsed. Total thoracoplasty, of course, by obliterating the space, eliminated function of the entire lung. It was found also in some cases that while roentgengrams and aspiration indicated that the pleural space had been obliterated, and consequently the patient was discharged, yet fluid still remained to cause trouble months, and sometimes years, afterward.

4. *Operations of the Schede type:* These procedures were frequently necessary especially when thoracoplasty failed. A Schede operation involved removal

of the ribs, periosteum, intercostal bundles and pleura, completely undecking the empyema cavity and then suturing the musculo-cutaneous flap onto the visceral peel and hoping that the graft would take. Frequently, it did not and the patient was left with a large chest wall defect which took years to heal. These Schede procedures caused marked deformity, not only to the thorax but, because the lower intercostal nerves were severed, there was marked herniation of the abdomen on the side of the operation, and patients with extensive Schedes are forced to wear complicated appliances in an attempt to counteract these abnormalities.

PATHOLOGY

It has seemed wise to discard the term "thickened pleura" to a great extent. In only a few cases is the pathology an inflammatory thickening of the visceral pleura itself. Almost always it consists of the laying down of hyalinized fibrous layers on the pleura.[1] This membrane is not intimately adherent in a large part, but is attached by a thin areolar vascularized layer which may be separated easily by blunt dissection, leaving behind an intact and, for the most part, fairly normal, expandable visceral pleura. This fibrous envelope may vary from a thin transparent filmlike layer to a thickness of one quarter of an inch or more. Regardless of thickness, the character of the loose areolar layer approximating the pleura is the same. In a few small areas there may be intimate attachment to the visceral pleura by tough scar, usually over areas of subjacent parenchymal disease. These areas may require sharp dissection for separation, or perhaps preferably they should be left in place. It would seem that the ease of decortication bears little relationship to the length of time the lung has been collapsed. The first patient to be presented in this series was a man who had had pneumothorax, oleothorax, and empyema for a period totalling in all thirty years. Decortication of his lung was surprisingly easy and successful.

CONTRAINDICATIONS TO DECORTICATION

It is felt that a definite contraindication to the performance of this procedure is the presence of an open focus in the underlying lung. In these cases, if it is considered that thoracoplasty will not collapse the cavity, a combined decortication and lobectomy is done. Some surgeons feel that decortication should not be carried out in pulmonary tuberculosis for fear of reactivating an apparently quiescent focus in the underlying lobe or lung. In the limited experience of this study, reactivation of the disease in the underlying lung did not occur. It is possible that this is, in a great part, due to the pre- and postoperative use of streptomycin.

PREOPERATIVE PREPARATION

As the procedure is elective, time is taken to make the patient's general condition as good as possible. Bronchoscopy is carried out to rule out active tracheobronchial disease, bronchostenosis (which would render expansion of the collapsed lung impossible even after decortication), and the presence of bacillary secretion from the lung to be operated on. The usual careful cardiovascular

examinations and vital capacity determinations are carried out. Streptomycin, one gram daily, and procaine penicillin G, 300,000 units once daily, is begun five days before the operation. Endotracheal anesthesia is considered to be mandatory, and pentothal induction followed by cyclopropane-ether-oxygen is preferred.

OPERATIVE TECHNIQUE

The incision is the usual posterolateral, one and the chest is usually entered between the fifth and sixth ribs after dividing them posteriorly. After cutting through the endothoracic fascia and parietal pleura, the outer parietal surface of the peel is reached. This is stripped away from the chest wall for a considerable area, and the rib spreaders are then inserted. This prior stripping of the parietal peel makes it possible to spread the ribs fairly widely apart so that an adequate exposure is obtained. The empyema cavity is entered, and an incision is then carefully made through the visceral peel until the shiny, bluish, visceral pleura comes into view. By combined blunt and sharp dissection, the visceral peel is removed entirely from the lung. The interlobar fissures are freed—a most important part of the procedure—and the parietal covering is then removed from the diaphragm, thoracic wall, and mediastinum. Areas of infolding of the surface of the lung are freed by sharp dissection. One occasionally runs across a case of true thickened pleura due to actual pleural inflammation, as in one of our patients. The visceral peel then will not strip, and, in his case, it was necessary to leave a sizeable section intact. However, there is usually enough expansion of the lung around such areas to obliterate the pleural space. Frequently, in removing the peel, the lung is damaged and at the close of the operation there are often lung air leaks. Many surgeons[1, 2, 7, 8] advise repairing these, but we feel that with proper postoperative management no harm is done by leaving them. The lung is then inflated by the anesthetist, two drainage tubes are placed, one in front at the apex and one posteriorly at the base, and the chest wall is closed in layers. Throughout the operation there is considerable oozing, and these patients require an adequate amount of blood replacement, the average being 2,000 c.c.

POSTOPERATIVE CARE

Postoperatively oxygen is administered for four to eight hours, and the tubes are connected alternately to a continuous suction apparatus. This is a most important part of the postoperative treatment, especially if there has been any lung air leak. It is usual to connect the anterior tube for two hours and the posterior one for one hour. Streptomycin and penicillin are continued, penicillin until the lung is completely re-expanded, and streptomycin and PAS for at least fifty days.

RESULTS

At the Nova Scotia Sanatorium, we have done one decortication for unexpandible lung, seven during the course of pulmonary resection and fourteen for

TABLE I. AGE AND SEX INCIDENCE RELATED TO INDICATION FOR OPERATION*

AGE GROUP	UNEXPANDABLE LUNG		WITH LUNG RESECTION		EMPYEMA		TOTAL
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	
10-19	0	0	2	1	0	0	3
20-29	0	0	0	4	2	5	11
30-39	1	0	0	0	2	0	3
40-49	0	0	0	0	4	0	4
50-59	0	0	0	0	1	0	1
All Ages	1	0	2	5	9	5	22

*The youngest was 13 years of age, the oldest 53 years.

tuberculous empyema. Age, sex, and the indication for operation are outlined in Table I. Briefly, our results are as follows:

In the one case of unexpandable lung without empyema, the illness began with spontaneous pneumothorax nineteen months previously in a man who had had his right arm amputated for a fibrosarcoma three years before. Spontaneous collapse occurred on the left side, and a roentgenogram following it revealed a density in the right mid-lung region which eventually excavated. Decortication on the left was decided upon with the view that exploration of the right chest might be necessary. The operation was done without difficulty, and it was possible to obtain a biopsy from the surface of the lung during the procedure. The lung re-expanded uneventfully. The pathologist's report was secondary fibrosarcoma.

In seven cases, decortication was done during the course of pulmonary resection (see Table II). The presence of the peel was explained by pre-existing pneumothorax in four cases. In one, the pneumothorax had been present for less than six months; in one, nine months; and in two, twelve to twenty-four months, respectively. Two patients had pneumothorax complicated by effusion, the duration of the latter in both instances being less than six months. In one patient, the presence of the peel could not be explained as there was no history of previous pneumothorax or pleural effusion. In all cases, the spaces became obliterated promptly following operation.

It is felt that decortication is of most value in the treatment of tuberculous empyema, and, before discussing results in the fourteen cases, in which the operation was performed for this indication, it might be well to present briefly the classification of tuberculous empyema in use at the Nova Scotia Sanatorium:

Type I—serous fluid positive for tubercle bacilli, underlying lung disease controlled.

Type II—serous fluid positive for tubercle bacilli, underlying lung disease uncontrolled

Type III—frank pus positive for tubercle bacilli, underlying lung disease controlled

Type IV—frank pus positive for tubercle bacilli, underlying lung disease uncontrolled

Type V—mixed infection

Obviously, decortication is not the best procedure for types II and IV, and some cases of type V where the underlying lung is not controlled will require some other procedure.

TABLE II. DECORTICATION ACCOMPANYING LUNG RESECTION; ETIOLOGY AND DURATION OF PEEL

ETIOLOGY	DURATION OF PEEL			
	UNDER 6 MONTHS	6 TO 12 MONTHS	12 TO 24 MONTHS	UNKNOWN
Artificial pneumothorax only	1	1	2	0
Artificial pneumothorax with effusion	2	0	0	0
No known reason	0	0	0	1
All reasons	3	1	2	1

TABLE III. DECORTICATION FOR EMPYEMA-TYPE AND ETIOLOGY OF EMPYEMA

TYPE	ARTIFICIAL PNEUMOTHORAX	PLEURISY WITH EFFUSION	POST-RESECTION OF LUNG TISSUE	TOTAL
I	2	1	0	3
III	6	1	0	7
V	2	1	1	4
All types	10	3	1	14

The type and etiology of the empyema are outlined in Table III. Of the three type I empyemas, two complicated artificial pneumothorax and one occurred spontaneously. Of the type III empyemas, six complicated artificial pneumothorax and one was spontaneous; and of the type V, two complicated pneumothorax, one was spontaneous and one occurred following lobectomy.

The results in decortication of empyema cases are outlined in Tables IV to VII, inclusive.

The empyema was classified as type I in three of the fourteen patients (Table IV). Each of these obtained a good result, and prompt, complete, obliteration of the space took place following decortication.

In seven patients, there was a type III empyema present. Of these, four obtained an excellent result with complete re-expansion; one is classified as improved, that is, there is a small residual space present; and two are classified as poor in that the empyema cavity became larger and required further surgical measures.

In four patients, the empyema was classified as type V, that is, mixed infection with bronchopleural fistula present. Surprisingly, all four of these patients obtained an excellent result following the operation. There were no deaths in the series.

In assessing the results of treatment as related to the duration of the empyema, three patients had their empyema more than two months but less than

TABLE IV. DECORTICATION FOR EMPYEMA; RESULTS ACCORDING TO TYPE OF EMPYEMA

TYPE	RESULT			TOTAL
	GOOD*	FAIR†	POOR‡	
I	3	0	0	3
III	4	1	2	7
V	4	0	0	4
All types	11	1	2	14

*Good—Complete obliteration of space.
†Fair—Small residual space.
‡Poor—Space same or larger.

TABLE V. DECORTICATION FOR EMPYEMA; RESULTS RELATED TO DURATION OF EMPYEMA

PREOPERATIVE DURATION OF EMPYEMA		RESULT			TOTAL
		GOOD*	FAIR†	POOR‡	
>2 mo.§	<1 yr.‖	3	0	0	3
>1 yr.	<2 yr.	3	0	1	4
>2 yr.	<5 yr.	2	0	0	2
>5 yr.	<10 yr.	2	0	0	2
>10 yr.	<21 yr.	1	1	1	3
All cases		11	1	2	14

*Good—Complete obliteration of space.
†Fair—Small residual space.
‡Poor—Space same or larger.
§> Greater than.
‖< Less than.

one year, and all three of these obtained good results (Table V). There were four in whom the duration of the empyema was more than one year but less than two years. Three of these obtained good results, and one is classified as poor. The latter is the patient in whom the operation had to be interrupted because of the deterioration of his condition on the table. Those with empyema more than two years but less than five numbered two, and both obtained an excellent result. There were two cases in which the complication had been present for more than five years but less than ten. Both spaces became obliterated completely. Three patients had empyema for more than ten years, and the maximum duration was twenty-one years. One of these obtained a good result, and in one the result was classified as fair and one as poor. In these two unsatisfactory cases, it was not possible to decorticate the diaphragm.

It would appear that the duration of the peel does not greatly affect the ultimate result.

It is of interest to relate the results obtained to the extent of the decortication, as shown in Table VI. Ten of the patients had complete decortication of the parietal and visceral peels. The entire group obtained good results. In four of the patients, the decortication was incomplete. In three of these, the diaphragm could not be decorticated, and in one the operation had to be interrupted because of the poor condition of the patient on the table. This last named patient obviously did not obtain a good result, and two of the three patients in whom the diaphragm could not be uncovered have small to moderate residual spaces at the base of the chests, emphasizing the desirability of completely decorticating the diaphragm if a good result is to be obtained.

In the eleven empyema patients who obtained complete expansion of the lung, obliteration of the pleural space occurred in ten to twenty-six days post-

TABLE VI. DECORTICATION FOR EMPYEMA; RESULTS RELATED TO EXTENT OF DECORTICATION

EXTENT OF OPERATION	RESULT			TOTAL
	GOOD*	FAIR†	POOR‡	
Complete	10	0	0	10
Incomplete	1	1	2	4
All cases	11	1	2	14

*Good—Complete obliteration of space.
†Fair—Small residual space.
‡Poor—Space same or larger.

TABLE VII. DECORTICATION FOR EMPYEMA; RESULTS RELATED TO EXTENT OF PARENCHYMAL DISEASE

EXTENT OF ORIGINAL LUNG LESION	RESULT			TOTAL
	GOOD*	FAIR†	POOR‡	
Minimal	1	0	0	1
Moderatively advanced	5	1	1	7
Far advanced	5	0	1	6
All cases	11	1	2	14

*Good—Complete obliteration of space.
†Fair—Small residual space.
‡Poor—Space same or larger.

operatively, seven of them taking under twenty days. The tubes were not removed until it was certain that the lung was everywhere adherent.

Only one patient was decorticated without lung leak, five had slight leakage of air, and in eight there was moderate to marked tearing of lung tissue. In the last named group, three obtained a poor result, but we feel, as mentioned above, that this was due not to leakage of air which was immediately removed from the chest by continuous suction, but to the incomplete decortication.

The amount of parenchymal disease present in the lung before collapse appeared to have little effect on the eventual results of decortication (Table VII). It was noted on one or two occasions that possibly one lobe appeared fibrosed and would not expand properly, but there occurred enough overexpansion of the remaining lobe or lobes to fill the space.

No estimations as to the increase in vital capacity due to the operation were made in these cases. The results recorded in the literature[5, 6] to date disagree as to how much increased function occurs. However, in this series, the prime concern was the treatment of the tuberculous empyema, the control of which depends on the prompt obliteration of the pleural space.

One patient only had a troublesome complication. In this case, some parietal pleura was inadvertently removed with the peel, and a considerable number of lung tears also occurred resulting in extremely marked surgical emphysema. The man was quite dyspneic for about ten days, but eventually made a good recovery with complete obliteration of the empyema space.

Short case histories of our fourteen empyema cases are presented.

CASE REPORTS

CASE 1.—D. C., white man, aged 53 years, developed pulmonary tuberculosis in 1917. Artificial pneumothorax was begun in 1918. It was maintained for twelve years and then replaced by oleothorax. The oleothorax was continued for five years. In 1938, a thoracoplasty was performed, but the space decreased only slightly in size. For the next ten years aspiration of thick pus was required three times weekly. Fluid was positive for tubercle bacilli (type V empyema). Bronchopleural fistula was demonstrated in 1948 and 1949. Pulmonary decortication was done in two stages, April 29, 1949, and May 13, 1949, with complete obliteration of the space.

CASE 2.—J. L., white man, aged 41 years, developed tuberculosis in 1926. Artificial pneumothorax was begun in 1927. A type III empyema developed during November, 1930. Aspirations were done frequently until January, 1932, when an oleothorax was substituted. The patient carried on in good health until September, 1948, when there was a recurrence of the emypema. The oil was removed and a complete thoracoplasty done from November,

1948, to January, 1949. The space was moderately decreased in size. In June, 1949, a pulmonary decortication was carried out. The diaphragm was not decorticated. The lung expanded well except at the base where a moderate-sized residual space remained. It was necessary, in March, 1950, to open this pocket widely. It was packed daily with PAS until March, 1951, when it appeared to have obliterated completely (classified as a fair result from decortication).

CASE 3.—L. C., white man, aged 24 years, developed pleurisy with effusion in January, 1948. The effusion became purulent and positive for tubercle bacilli. After several months of aspirations, a pulmonary decortication was done Oct. 7, 1949. The patient's condition became poor on the table when only the lower lobe had been decorticated and the operation had to be interrupted. The space persisted in spite of frequent aspiration, but the patient's condition was not good enough to undertake further surgery until Feb. 27, 1951, at which time two separate empyema pockets were entered and the visceral peel in these areas removed. When this was done, it was found that insufficient lung expansion was occurring. Consequently, portions of the second to the eighth ribs were removed subperiosteally. The postoperative course was extremely stormy, with marked spread to the contralateral lung. However, this disease has now almost completely resolved, and the empyema space appears to be completely obliterated (classified as a poor result from decortication).

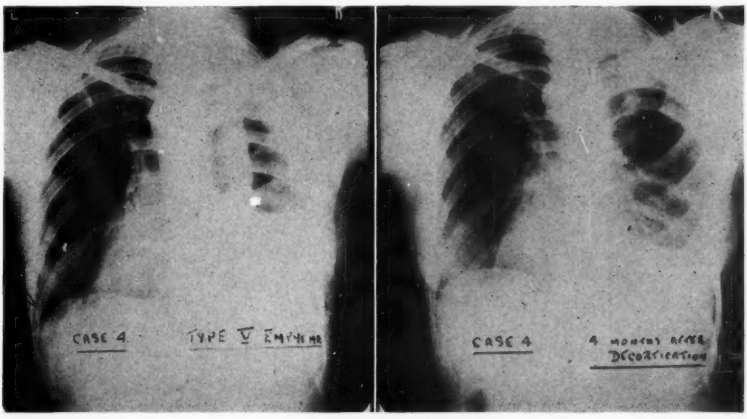

Fig. 1.—Case 4. Roentgenogram of chest before and after decortication. One of early cases requiring resection of a rib.

CASE 4.—J. R., white woman, aged 28 years, developed tuberculosis in 1946. A right artificial pneumothorax was initiated, and in January, 1947, an intrapleural pneumolysis was carried out. A massive hemopneumothorax followed and, in a matter of weeks, this became a fibrothorax. The patient's general condition improved and sputum became negative, so it was decided that she probably would not require further treatment. However, in 1948, a type V empyema with bronchopleural fistula was demonstrated. Pulmonary decortication was done on May 6, 1949, with prompt re-expansion of the lung (Fig. 1).

CASE 5.—M. T., white woman, aged 27 years, developed tuberculosis in 1948. Pneumothorax was attempted, but pleural symphysis was found. A left phrenic crush was done in December, 1948, and in March, 1949, pneumoperitoneum was begun. Atelectasis of the left upper lobe with cavity formation appeared, and in October, 1949, a left upper lobectomy was done. Following operation, a clotted hemothorax developed and was soon followed by bronchopleural fistula and the development of a type V empyema. Pulmonary decortication was done Dec. 2, 1949, with complete obliteration of the pleural space (Fig. 2).

CASE 6.—N. S., white woman, aged 24 years, developed tuberculosis in 1945. A right pneumothorax was begun in August, 1946. An effusion developed some months later and became a type III empyema in February, 1948. In spite of continuous aspiration, the lung did not expand. A right pulmonary decortication was done on Jan. 27, 1950, with prompt obliteration of the pleural space. The patient remained well until October, 1950, at which time a small new infiltration was noted in the left apex. This is still present and will probably require further treatment.

CASE 7.—J. M., white man, aged 44 years, developed tuberculosis in January, 1943. Left pneumothorax was begun during April, 1944, and a type I empyema developed in March, 1947. In spite of frequent aspirations, the lung did not re-expand. Pulmonary decortication was carried out on Feb. 20, 1950, with prompt obliteration of the space (Fig. 3).

CASE 8.—A. H., white man, aged 31 years, developed a right-sided pleurisy with effusion during June, 1941. This became purulent and positive for tubercle bacilli in 1942. With aspirations, it was thought that the space had obliterated, and the patient remained well until September, 1948, when a type V empyema with bronchopleural fistula developed. After a period of frequent aspirations a right pulmonary decortication was done on May 17, 1950. There was complete obliteration of the empyema cavity.

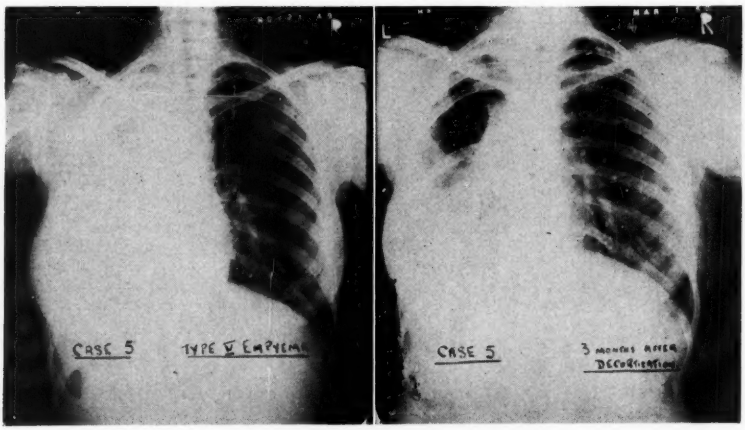

Fig. 2.—Case 5. Roentgenogram of chest before and after decortication. Also an early case for which a rib was resected.

CASE 9.—H. C., white man, aged 34 years, developed tuberculosis in 1931. Artificial pneumothorax was begun promptly, and carried on for three years when the lung was allowed to re-expand. An opacity at the base was thought to be "thickened pleura." The patient remained well for fifteen years. In January, 1949, he developed a severe cough and sputum with streaking. Purulent fluid positive for tubercle bacilli was aspirated from the right chest. Continuous aspiration, phrenic crush, and pneumoperitoneum were unsuccessful in obliterating the space. Pulmonary decortication was done in April, 1950. The diaphragm could not be decorticated. Prompt re-expansion did not occur, although the space seemed to be getting smaller. In August, 1950, a marked reaccumulation of pus occurred with high fever and chills. Open drainage was carried out, and the residual space gradually decreased until now, eight months later, its capacity is about 10 c.c. (classified as a poor result from decortication).

CASE 10.—M. C., white woman, aged 23 years, developed a right-sided pulmonary tuberculosis in the spring of 1949. A pneumothorax was induced March 30, 1949, and in

February, 1950, a type III empyema developed acutely. Strenuous attempts were made to expand the lung, but these failed. Pulmonary decortication was performed on May 9, 1950, and the space was obliterated in forty-eight hours (Fig. 4).

CASE 11.—J. L., white man, aged 20 years, developed tuberculosis in 1944. For the next four years his course was rather unstable, and by March, 1949, bilateral pneumothorax had been initiated. Following a right intrapleural pneumonolysis in August, 1949, a type I empyema developed. In spite of frequent aspirations, the lung proved unexpandable, and a pulmonary decortication was done on May 12, 1950. There was prompt and complete obliteration of the empyema cavity.

CASE 12.—J. B., white man, aged 40 years, developed bilateral pulmonary tuberculosis in 1941. in 1943, a left artificial pneumothorax was begun. A type III empyema developed during July, 1945, and the space was thought to have been obliterated by aspiration by October, 1948. However, in July, 1949, purulent fluid was again found in the pleural space.

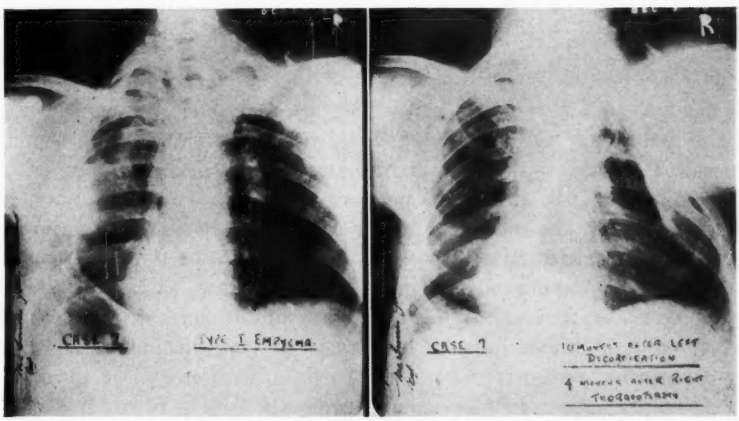

Fig. 3.—Case 7. Decortication carried out on left side to increase vital capacity and so permit thoracoplasty on right. Roentgenograms of chest before and after operations.

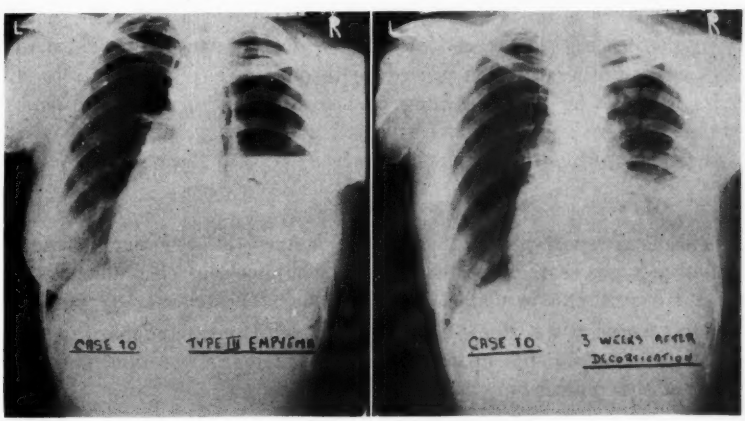

Fig. 4.—Case 10. Chest roentgenograms before and after decortication. Patient left Sanatorium four weeks after operation.

Aspirations were continued without avail. A left pulmonary decortication was done Oct. 13, 1950. The postoperative course was rather stormy because of the development of marked subcutaneous emphysema. This subsided, however, and the lung re-expanded completely.

CASE 13.—R. M., white woman, aged 22 years, developed bilateral tuberculosis in 1947. Bilateral artificial pneumothorax was induced, and that on the left side was maintained for two and one-half years. On the right, a type III empyema developed in February, 1950. Sputum remained positive, and bronchiectasis was demonstrated in the right upper lobe. The empyema persisted and in October, 1950, a complete pulmonary decortication was done and the right upper lober was removed. After a period of several weeks, complete obliteration of the space occurred.

CASE 14.—M. M., white man, aged 48 years, developed tuberculosis during 1946. A left-sided artificial pneumothorax was initiated in February, 1947, and this was complicated by a type I empyema during February, 1948. Repeated unsuccessful attempts were made to re-expand the lung by aspiration. A left pulmonary decortication was carried out on March 6, 1951, with rapid and complete obliteration of the pleural space.

DISCUSSION

Although our experience is limited, we are very much impressed with the results of pulmonary decortication, especially in the treatment of tuberculous empyema. It would appear that in these cases a decortication properly and completely done will be almost 100 per cent effective in effecting a cure. It is our impression that the success of the operation will be in direct ratio to the completeness of the decortication, particularly with respect to the removal of the peel from the diaphragm. It is also very important, as far as possible, to free the interlobar fissures. While every attempt is made to treat the lung with respect, it is almost impossible to avoid a small amount of air leakage. When continuous suction is used, however, this does not appear to affect the outcome and the lung usually re-expands promptly.

The so-called unexpandable lung without empyema would seem particularly suited to this operation, as in these cases the peel is usually thin and very loosely attached and there is no infection present. In regard to resection, the availability of the decortication procedure renders unnecessary the performance of thoracoplasty or other collapse procedure to obliterate a space that could not otherwise be filled by the remaining peel-covered lobe or lobes. Pneumonectomies that were once thought impossible are now greatly simplified by the finding of the cleavage plane between the visceral peel and the visceral pleura.

SUMMARY

1. This is a report of results with pulmonary decortication in the treatment of twenty-one cases of various pleural complications of pulmonary tuberculosis and one of unexpandable lung in pulmonary sarcoma.

2. The operation was done on one patient with unexpandable lung and no infection, on seven patients in the course of pulmonary resection, and in fourteen cases of tuberculous empyema.

3. Results were good in eleven of the fourteen empyema cases, that is, there was complete obliteration of the pleural space; one was classified as a fair re-

sult, that is, the space, while becoming smaller, did not completely obliterate; and two are classified as poor in that there was no decrease in the size of the empyema cavity without the assistance of further surgery.

4. It is considered that pulmonary decortication is the most valuable procedure available for the treatment of the aforementioned complications.

5. Brief case histories of the fourteen empyema cases are presented.

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UNUSUAL STERNAL DEFORMITY WITH CARDIAC SYMPTOMS—OPERATIVE CORRECTION

MARK M. RAVITCH, M.D.
BALTIMORE, MD.

A NUMBER of structural deformities of the chest wall have been corrected by operative procedures, among them split sternum[1] and scoliosis,[2] but the thoracic deformity which is most commonly treated surgically is the deformity of the sternum known as pectus excavatum, or funnel chest. That condition is congenital, often familial, and generally progressive. There is a depression of the sternum sweeping down from the manubrium to the point of maximum depth in the lower portion of the corpus sterni. There is also an accompanying side-to-side concavity of varying depth. In most instances these patients develop a flat thin chest, a dorsal kyphos, and tend to carry their heads thrust forward. They are generally thin, puny, poorly developed individuals. In some instances, and far more commonly than is generally realized, the depressed sternum presses upon or displaces the heart, producing demonstrable physiologic disturbances. In the mildest cases there may be nothing more abnormal than electrocardiographic evidence of cardiac displacement and rotation. There may be various types of cardiac arrhythmia, there may be decrease in exercise tolerance and even cardiac failure.[3] Operation in pectus excavatum is indicated to correct the existing deformity, to prevent its progression, and to relieve symptoms which may have already occurred in those patients not operated upon in childhood.

In the present instance the sternal deformity was of an unusual type. It resembled that in pectus excavatum in that the depressed corpus sterni displaced the heart to the left, producing symptoms. However, the deformity differed from that seen in pectus excavatum. This patient was a powerfully built young man with a deep chest and good expansion. The angulation of the sternum was a double one, with an anterior bowing in the superior portion in addition to the usual concavity inferiorly. Unlike the condition in pectus excavatum, the ribs seemed to be little involved in the deformity, and there was therefore little side-to-side concavity. There was no paradoxical motion of the sternum. Operation was undertaken because of increasingly frequent attacks of what sounded like paroxysmal tachycardia.

CASE REPORT

J. H. H., No. 463381.—The patient was an 18-year-old college student admitted for treatment of a congenital deformity of his chest. No similar deformity was known to be

From the Department of Surgery of The Johns Hopkins University and The Johns Hopkins Hospital.
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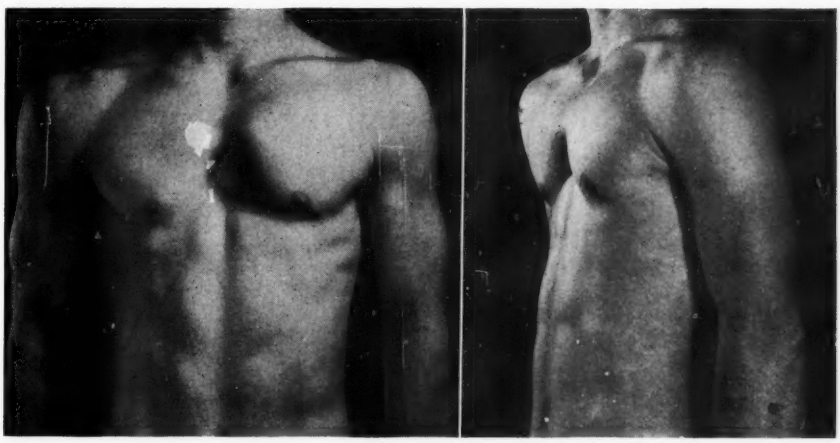
present in any member of his family. The peculiar conformation of his sternum had been noted at birth, and it had become progressively more obvious as he grew. There was no limitation in his exercise tolerance. The only symptoms which were attributable to his deformity consisted of attacks of palpitation followed by apparent slowing of the heart-beat, and heavy breathing. For about a year before admission to the hospital these attacks had occurred about once a month. He sought medical attention because of these attacks. Examination showed a powerfully built young man in excellent general health. He had a peculiar deformity of the sternum such that the manubrium stood outward from the sternomanubrial junction at an angle, thrusting forward to give him the appearance of a pouter pigeon (Fig. 1). At the junction between the manubrium and the gladiolus, the sternum angled sharply posteriorly, and again at the lower portion of the gladiolus the sternum tilted sharply forward. The deep cavity produced by the combination of these angulations served to thrust the lower portion of the body of the sternum against the heart, for roentgenograms showed a moderate displacement of the heart to the left. There was also a failure of fusion of the laminae of the second thoracic vertebra. Films taken in inspiration and expiration showed clearly that there was a definite increase in the anteroposterior diameter of the chest during inspiration, with normal descent of the diaphragm. The lateral views showed sharply the double angular deformity of the sternum with its S or Z profile (Fig. 2). The cardiac rhythm was regular and the electrocardiogram showed only a right axis deviation.



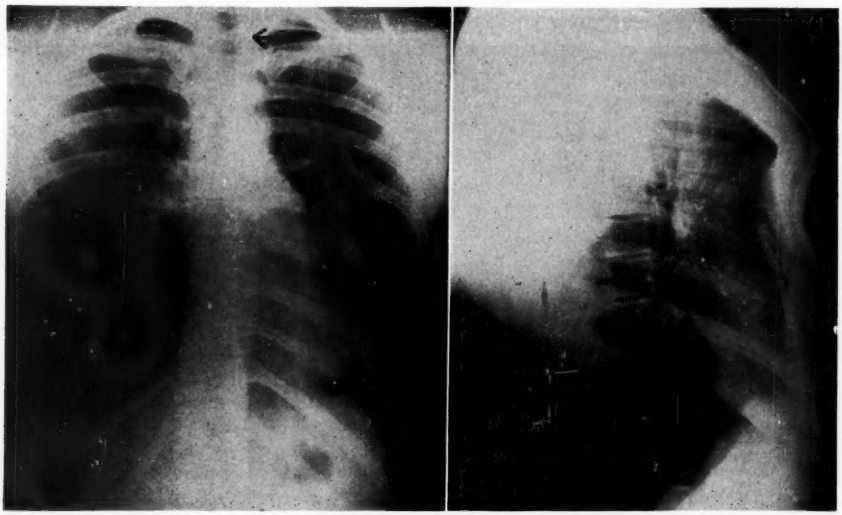
A. *B.*

Fig. 1.—*A* and *B*, Note the curious conformation of the chest. The manubrium slopes broadly forward to the manubriogladiolar junction where there is a sharp angulation. From this point the gladiolus inclines posteriorly to the lower third of the corpus sterni where the slope reverses itself and the sternum tilts anteriorly. Notice the powerful musculature and full chest, quite unlike that seen in the ordinary pectus excavatum.

Because of the history of progression of the deformity with the recent appearance of symptoms apparently attributable to it, it was felt that the symptoms could probably be relieved by correction of the deformity. This was considered not to be a typical pectus excavatum because of the sharp double angulation and because of the normal expansion of the chest without any evidence of general flatting of the chest, decrease in the anteroposterior diameter or paradoxical motion.

On June 11, 1948, under intratracheal ether anesthesia, the deformity was corrected. A midline incision was made from above the prominence of the gladiolomanubrial junction to a point well down on the epigastrium. The pectoral muscles and recti were peeled away.

The five lowermost costal cartilages on each side, which were attached to the deformed portion of the sternum, were divided, and short segments of each were resected. Inasmuch as the deformity did not extend very far laterally and the ribs were not deformed or distorted, only short segments were removed. The xiphoid was divided from the sternum and a fairly tough ligament behind it was also divided. Tough fibrous attachments between the lower portion of the sternum and the diaphragm were divided, visibly freeing the sternum. The portion of the sternum thus isolated was freed of all attachments to intercostal muscles and mediastinal tissues. The pleura was entered on the right. A transverse cuneiform osteotomy was performed at the level of greatest prominence of the convex deformity and the sternum lifted anteriorly, fracturing the posterior cortical lamella until at this point the sternum and gladiolus were level with each other. Since the lower portion of the sternum still had a concave deformity, the effect was to produce an uptilting of the lowermost portion of the sternum. This was corrected by cutting with an osteotome through most of the thickness of the sternum at the deepest point of the concavity and fracturing the lower portion of the sternum backwards, completing the realignment of the sternum. Portions of the costal cartilages were left attached to the sternum because they did not appear deformed unlike the situation characteristic of the ordinary pectus excavatum.



A. *B.*

Fig. 2.—Preoperative roentgenograms. *A*, Posteroanterior view. The heart is displaced to the left. The arrow points to a failure of fusion of the laminae of the second thoracic vertebra. *B*, Lateral view. The sternal contours are accentuated by application of barium paste to the skin. The upward and forward displacement of the manubrium and the Z- or S-shaped profile of the sternum with two angulations are plainly demonstrated. In inspiration, the transverse diameter of the thorax is considerably greater than in expiration.

The cuneiform gap in the superior transverse osteotomy was closed by lifting the sternum anteriorly, and the bone was held in the corrected position at this level by three braided silk mattress sutures placed through drill holes. It was now found that the stumps of the superior most costal cartilage on either side could be sutured together with heavy silk. In order to keep the lower transverse sternal osteotomy open so as to tilt the distal segment downward and to maintain correct alignment with the body of the sternum, the bone chips removed in making the cuneiform osteotomy were packed into the open defect in the lower

transverse sternal osteotomy, thus maintaining the sternum in excellent alignment (Figs. 3 and 4). The right pleura was penetrated. The patient tolerated the operation quite well although whenever the manipulation of the sternum became too forceful his blood pressure would drop from 120 mm. mercury systolic to 90 mm. mercury systolic. He received 1000 c.c. of blood in the course of the procedure.

Of great interest was the observation that when the chest was first exposed there was no room for a finger between the heart and the lower portion of the sternum which pushed directly against it, whereas at the conclusion of the operation after the division of the costal cartilages and all of the intercostal muscles on both sides and refracturing of the sternum, there was at least two fingerbreadths between the posterior border of the sternum and the heart. At the conclusion of the procedure the air which had entered the right pleural cavity was aspirated.

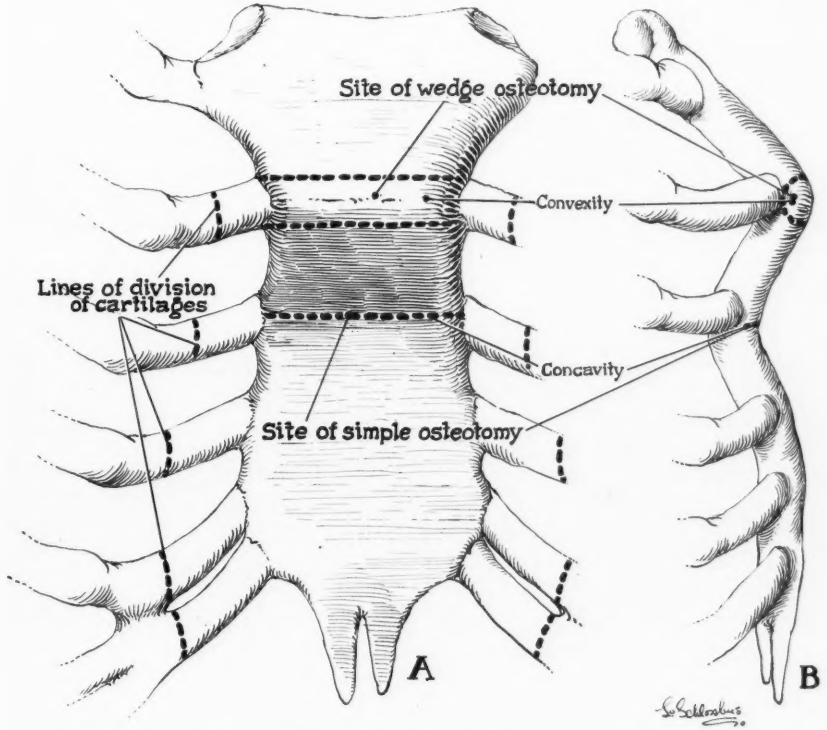


Fig. 3.—D. R. The sternum has two fairly sharp angulations. The manubrium juts out much more prominently than usual. The angle of Louis is extremely acute, and this angulation seems to emphasize the more caudal angulation which is in the reverse direction. The sternum is unusually broad, and the xiphoid is bifurcated.

The patient ran a decreasing elevation in temperature for four days after operation and accumulated a moderate amount of fluid in the right hemithorax which had to be aspirated on several occasions. There was never any evidence of paradoxical respiration. He was out of bed on the fourth day after operation, and left the hospital on the tenth day. A very satisfactory correction of the deformity was secured as evidence by his outward appearance (Fig. 5) and by the roentgenograms (Fig. 6).

He was last seen Nov. 30, 1950. He stated that since operation he had had no more of the series or runs of palpitations such as he had been having at monthly intervals before, but that occasionally he still had single momentary shocklike sensations as if his heart had missed a beat. His exercise tolerance and vigor were essentially as they were before operation and he was delighted with the cosmetic result. Examination showed maintained correction of the sternal deformity. The anterior border of the sternum was smoothly and nicely rounded. There was an inconspicuous midline scar. The sternum felt perfectly solid and

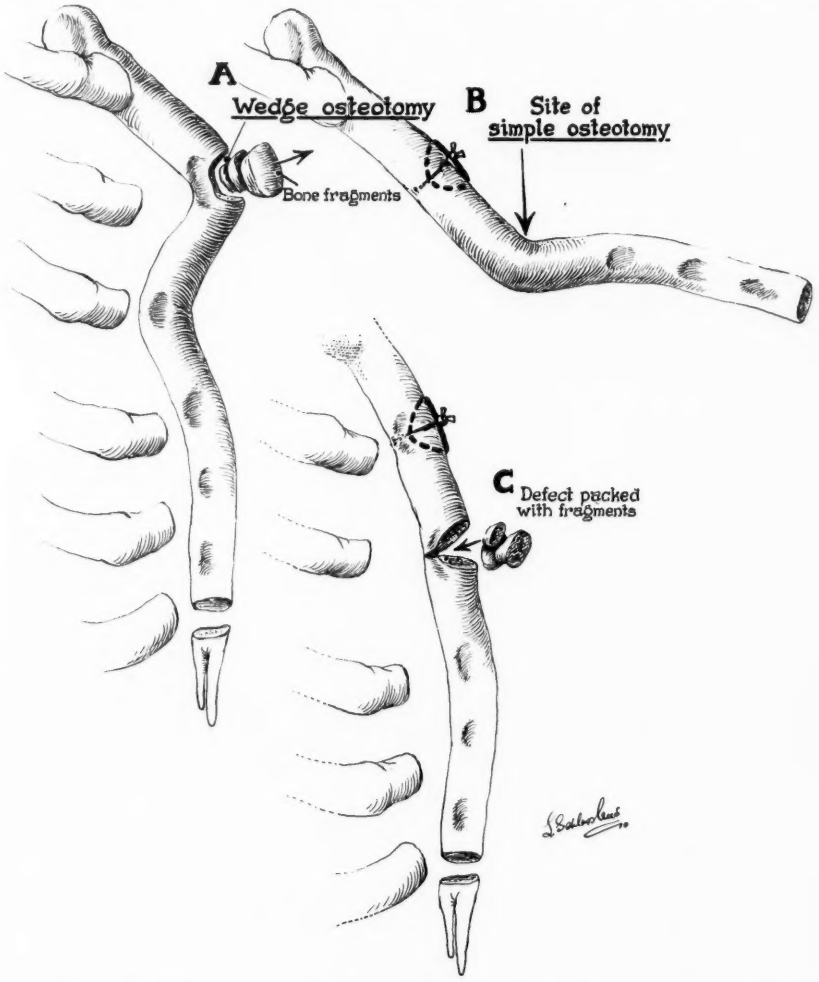


Fig. 4.—Plan of operation. After resection of segments of five costal cartilages on both sides and division of the xiphi sternal junction, two osteotomies were performed. Superiorly, a wedge osteotomy permitted the sternum to be lifted anteriorly, fracturing the posterior cortical lamella and restoring a natural alignment, as shown in *B*. This resulted in an anterior tilting of the lower portion of the corpus sterni. A simple osteotomy at the appropriate level permitted the sternum to be fractured posteriorly. The osteotomy thus opened out was packed with the fragments from the wedge osteotomy and the corrected position maintained without sutures. Superiorly, the manubrium and gladiolus were sutured together across the osteotomy with heavy braided silk. No traction or external splinting was employed.

one could not palpate any defect in the costal cartilages lateral to it. Inferior to the sternum and between the tip of the sternum and the epigastrium was a moderate sized midline defect representing the gap between the sternum and the xiphoid. The lower costal cartilages extending over from the costal margin met almost in the midline over this defect in the bony structure.

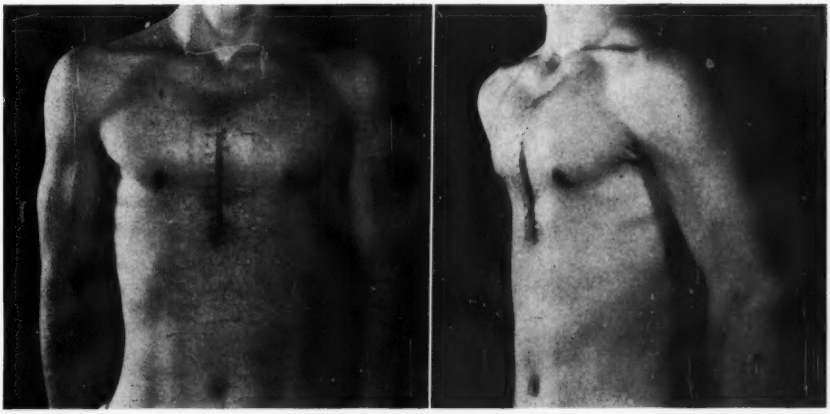


Fig. 5.—*A* and *B*, Ten days after operation. The chest has a much more normal contour, although the basic forward tilt of the manubrium remains, and, the depression of the corpus sterni having been corrected, the chest seems rather prominent. The improvement is maintained without alteration two and one-half years later.

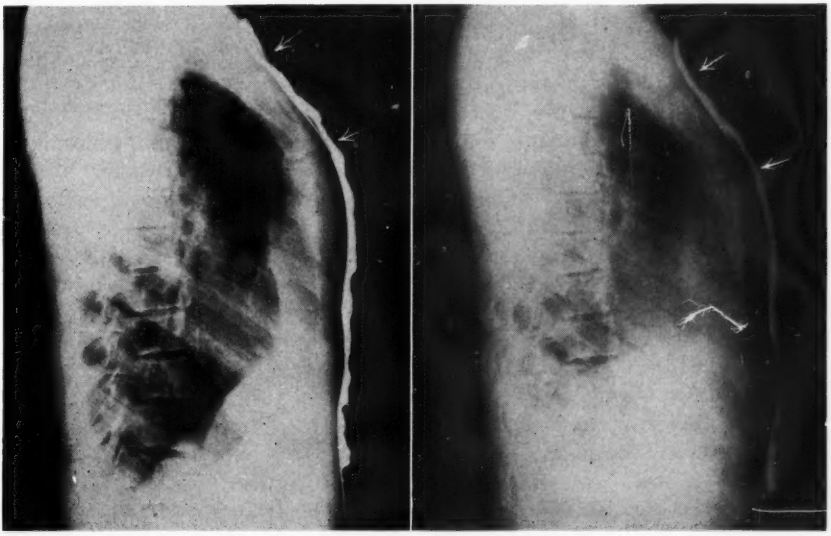


Fig. 6.—*A* and *B*, Postoperative roentgenograms. *A*, Inspiration; *B*, expiration. The chest wall is now smoothly rounded and the Z-shaped silhouette of the sternum has been corrected. The arrows point to the sites of the two osteotomies. The superior osteotomy at the manubriogladiolar junction is a wedge osteotomy, the sternum being then forcibly angulated anteriorly, fracturing the posterior cortical lamella. The lower osteotomy was spread open by fracturing the distal sternum posteriorly. Bone chips from the first osteotomy were placed in the second as wedges to hold it open. There is good expansion of the chest.

COMMENT

In this instance an atypical funnel chest appeared to produce cardiac symptoms. The operation differed from that usually employed[4] in that two transverse osteotomies were required; very short segments of five costal cartilages on each side were resected and the sternal ends of all of them were left long. It was actually possible to resuture the second costal cartilages to the sternal ends. The correction secured was entirely satisfactory, and the symptoms appear to have been relieved. An operation of this magnitude in a powerfully built adult is a considerable procedure. There is every reason to undertake such procedures in childhood when structures are smaller and more readily handled and the deformity less pronounced.

From the technical standpoint it is of interest that even in this heavily muscled man with an unusually thick broad heavy sternum, no external traction was required and silk sutures alone securely maintained the sternum in corrected position. Three years later the chest is solid, and the achieved correction has been maintained.

SUMMARY

A case is reported of a curious and atypical sternal deformity in an 18-year-old boy who had increasingly frequent attacks of paraxysmal tachycardia apparently due to pressure upon the heart and displacement of it.

Resection of small segments of five costal cartilages on each side, division of the xiphi sternal joint, and transverse osteotomies of the sternum at each of the levels of angulation corrected the deformity and relieved the symptoms.

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EPIPHRENIC DIVERTICULA OF THE ESOPHAGUS

HENRY I. GOODMAN, M.D., AND IRVING H. PARNES, M.D.
NEW YORK, N. Y.

EPIPHRENIC diverticulum of the esophagus is a rarity. After exhaustive study of all the medical literature, 126 reported cases were found. These were the cases that were sufficiently described to be reliable enough to be included. Many reported cases were found not to be true epiphrenic pulsion diverticulum, and therefore were not included in this report. A distinction must be made between true epiphrenic diverticula and traction, or functional diverticula that have other significance. An epiphrenic diverticulum is one that is located just above the diaphragm, and constitutes a pulsion or pressure diverticulum. The diverticulum will contain all the layers of the esophagus; the weakness, however, being most likely in the muscular layer of the esophagus. There are several theories as to why the muscular layer is weak. It may be congenitally weak or weakened by a localized esophagitis, and the constant pressure of the food upon a congenita'ly weak portion causing a diverticulum. This constant pressure may be greatly increased due to an atresia of the lower end of the esophagus or a neurogenic cardiospasm so that a normal musculature may be weakened. There may be destructive degenerative changes of intramural ganglia in the region of the esophagus that may weaken the muscular layer. Another interesting fact is that about 65 per cent of the cases of epiphrenic diverticulum have an associated cardiospasm. This might be due to similar neuromuscular defects or it may be secondary, due to reflex action originating in the inflamed wall of the diverticulum of the esophagus.

The first reported cases were those found in autopsy material. With the advent of the roentgen ray, the diagnosis could definitely be made more frequently. Symptoms of the diverticula of the esophagus were usually not very clear cut or directly related to the esophagus. Many of the cases reported were incidental findings, although some of the patients had one or more symptoms referable to the gastrointestinal tract leading to roentgenographic studies. Those patients who had symptoms directly referable to the esophagus had one or more of the following complaints: dysphagia, epigastric pain or soreness, vomiting or regurgitation, substernal distress, gas on the stomach, anorexia, belching, bloating, loss of weight, cough, bad breath, gurgling noises in the sac, heartburn, nausea, regurgitation of blood, and hiccough. The severity of the symptoms varies from very slight to severe enough to cause inanition and even emergency operation.

Depending on the severity of symptoms, the treatment varied. Many of the reported cases had no therapy at all; others had no more than bland diets,

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TABLE I. ALL RECORDED CASES OF EPIPHRENIC DIVERTICULA AND THE METHOD OF TREATMENT

AUTHOR	YEAR	NO. OF CASES	TREATMENT		RESULT	REFERENCE	COMMENT
			CONSERVATIVE	OPERATIVE			
Hausman		1	1			14	
Stark		1	1			14	
Tenenes		1	1			14	
Oekonimedes	1882	1	1			14	
Reitzenstein	1898	1	1			14	
Borsche	1900	1	1			14	
Jung	1900	1	1			14	
Zweig	1901	1	1			14	
Kaufman	1909	1	1			14	
Keinbock		1	1			14	
Steirlein	1916	2	1	1	Died	10	Transpleural excision of sac. Died of leakage of suture line
Enderlen	1910	1		1	Died	10	Extrapleural excision of sac. Died of cardiac failure
Carman	1920	1	1			14	
Freund	1921	3	3			14	
Dachter	1921	1	1			14	
Clairmot	1921	1		1	Successful	32	Resection extrapleurally
Bensomde	1922	2	2			14	
Haenioche	1923	1	1			14	
Dessecker	1923	1	1			10	
Kramer	1924	1	1			14	
Henschen	1924	2		2	1. Successful 2. Successful	19	1. Diverticulo-gastrostomy (intrathoracic) 2. Fistula made between stomach and diverticulum (abdominal approach)
Horst	1925	2	2			14	
Vogel	1925	1	1			14	
Guertz	1925	1	1			14	
Nicon	1925	2	2		1 Died 1 Fair		
Sauerbruch	1927	1		1	Successful	26	Excision of sac
Moynihan	1927	2	2			32	Dilation of cardiac end of esophagus with bougies in 1 case and through thoracic gastrostomy in 1 case
Smith, L. A.	1928	2	2			14	
Wright	1928	1	1		Fair	47	
Burgess	1928	1		1	Successful	43	Intra-abdominally dilated cardiac through stomach, pulled esophagus down, excised diverticulum and anastomosed esophagus to stomach

TABLE I—CONT'D

AUTHOR	YEAR	NO. OF CASES	TREATMENT		RESULT	REFERENCE	COMMENT
			CONSERVATIVE	OPERATIVE			
Raoust	1928	1	1		Poor	36	
Sessior	1928	1	1			14	
Fitzgibbons	1929	1	1			14	
Gally and Bernard	1929	1	1		Good	14	Dilation of cardiospasm with bougies
Fiek	1929	1		1	Successful	12	Transpleural approval, removal of sac, section of phrenic nerve and fashioning of pedicle flap of diaphragm which was sutured over esophagus wound
Tiprez	1930	1	1			44	
Quartero	1931	1		1	Fair	36	Transpleural resection. Slight insufficiency of sutures and leak which closed
Parcelier	1932	1		1	Died	34	Transpleural resection. Died of erosion into aorta
Adam	1933	1		1		14	Abdominal approach for diverticulectomy
Granet, E.	1933	1	1	1		14	
Raven	1933	1	1			39	
Barrett	1933	1		1		4	Resection extrapleurally
Vinson, P. P.	1934	24	Medical (All)		Variable	46	Two double diverticula. One multiple diverticula
Lederer, A.	1934	1		1		25	
Kosenork, B. D.	1935	1	1			33	
Hautefeuille	1936	1	1			17	
Chevallier	1936	1	1		Fair	7	
Neuber	1938	3	2	1	Fair	33	Transthoracic diverticular resection. Fistula for 3 months, requiring thoracoplasty for closure
Lelong	1938	1	1		Good	27	Infant
Milanes	1939	1	1			30	
Harrington	1940	4		4	Successful	16	Resection transpleurally
Holinger	1940	1	1		Fair	20	Double diverticula in lower one-third of esophagus. (Dilatation of esophagus)
Chebotarev	1940	4	4			7	
deAmesti	1944	1		1	Successful	9	Transpleural excision
Udando	1944	1	1			45	
Abbott	1945	1		1	Died	1	Esophago-gastrostomy. Transpleural complicated by empyema and pericardia esophageal fistula
Janes	1946	4		4	Successful	21	Resection transpleurally

TABLE I—CONT'D

AUTHOR	YEAR	NO. OF CASES	TREATMENT		RESULT	REFERENCE	COMMENT
			CONSERVATIVE	OPERATIVE			
Ramos	1947	1	1			37	
Schena	1947	1		1		42	Resection extrapleurally
McNealy and Glassman	1947	1		1	Successful	29	Intra-abdominal esophagogastrostomy
Kay, E. B.	1947	2	1	1	Successful	23	Resection extrapleurally
Forrester-Ward, M. N.	1948	1		1	Successful	13	Resection extrapleurally
Monod	1948	1		1	Successful	31	Excision of sac complicated by lung abscess most likely caused by diverticulum
Smelt	1948	1		1	Successful	43	Transthoracic excision
Lahey	1948	8		8	Successful	24 2	(1) Suture of sac upward dependent drainage (2) Resection of sac transpleurally
Poppe and Berg	1949	1		1	Successful	35	Transthoracic esophagogastrostomy
Harrington	1949	4		4	Successful	16	3 Diverticulectomy. 1 Invagination of small diverticulum with plication of dilated walls of esophagus
Johnstone	1949	3	3			22	
D'Abreu	1949	1		1	Successful	8	Congenital type in 6-year-old girl. Diverticulectomy and lobectomy for concomitant bronchiectasis

sedatives, and antispasmodics. Other types of palliative therapy consisted of sporadic lavaging of the sac or dilation of the cardiac end of the esophagus with hydrostatic dilators or sounds. More definitive therapy was gastrostomy, but that was done only when the sac becomes so large that it would not permit normal alimentation or when esophagitis in and around the sac did not allow oral feedings.

Of the 126 reported cases, forty-three, or 33 per cent, were operated upon for treatment of the epiphrenic diverticulum. Of these forty-three cases, there were only four operative deaths, a mortality of 9 per cent. However, the use of surgery to correct the symptoms of epiphrenic diverticula of the esophagus has only recently been generally adopted. The reasons for this late start in surgical treatment was the fear of the earlier surgeons of intrathoracic surgery. Entering the pleural cavity was not safely accomplished until the methods of controlled anesthesia, especially the development and improvement of endotracheal anesthesia, the improved methods of blood transfusion and resuscitation, and the use of chemotherapy and antibiotic therapy were in general use. The other barrier to esophageal surgery was the lack of a peritoneal covering to the esophagus, thereby making for a more precarious suture line. However, with

careful technique and gentle handling of the tissues and care in maintaining the blood supply of the esophagus, this handicap has for the most part been overcome.

The operation of choice is one which would eradicate the pathologic lesion, the diverticulum, and the obstruction or spasm at the cardiac end of the esophagus. There have been many operations done, indicating that one type of operation will not cover all types of pathology. Among the operations performed were: extrapleural resection of sac (Enderlen and Fick), diverticulogastrostomy, abdominally (Lotheissen) or by the transthoracic approach (Henschen and Poppe), invagination of small diverticulum (Girard), suspension of the diverticulum for dependent drainage (Lahey and Holinger), and transpleural resection of sac and direct suture (Quartero, Harrington, Janes, etc.).

The indications for operation are:

1. A diverticulum, which because of its size interferes with deglutition or which because of stasis has infected retained food within, causing various gastrointestinal symptoms.

2. A diverticulum which is associated with referred pain due to pressure on the vagus or sympathetic nerves.

3. A diverticulum which is associated with cardiospasm or associated with atresia of the esophagus, congenital or acquired, which would interfere with proper nutrition.

4. A diverticulum which has become ulcerated causing localized peptic esophagitis.

5. A diverticulum that may undergo malignant changes.

It is agreed that the best approach to the esophagus is the transthoracic one, and that the extrapleural approach should no longer be used. The abdominal route is almost always an inadequate method for complete exposure, and is not now frequently used. With the perfection of fine silk technique and meticulous repair, the Lahey suspension operation has been discarded for the complete operation of diverticulectomy. The operation that has been most adequate to date has been the resection of the sac over clamps and the careful closure of the esophageal defect. This is all done in one stage, inasmuch as the location within the pleural cavity does not allow exteriorization for a two-stage procedure. In difficult cases, or when the diverticulum was too large or too close to the diaphragm, an anastomosis was done between the diverticulum and the stomach. This has proved fairly satisfactory, but it is not a complete operation.

The method of treating the diverticula and the atresia of the esophagus presented here has not heretofore been reported in the literature. This method consists of resection of the distal portion of esophagus containing the diverticula, the area of atresia, and anastomosing the esophagus to the stomach which is brought up into the chest. This allows for the complete eradication of the lesion and for the use of the gastric peritoneal layer to reinforce the suture line of the anastomosis.

CASE REPORT

J. M. (Flower and Fifth Avenue Hospital, No. 5957), a white woman, 54 years old, was admitted on July 3, 1947, because of increasing difficulty in swallowing.

History: For the past year, the patient noticed increasing difficulty in swallowing. This condition progressed so far that on admission she could swallow only water. Most solid foods, excepting farina, could not be swallowed. Her weight dropped from 143 pounds to 98 pounds. Seven years previously, the patient had developed a generalized osteoarthritis, progressively involving practically all joints. This osteoarthritis compelled her to become a semi-invalid. For the past few months, there had been very little pain from her arthritis. Past history was noncontributory.

Fig. 1.—Case 1. Radiograph showing double diverticulum at lower end of esophagus and associated constriction.

Physical Examination: The patient presented the picture of a generalized arthritis enforcing confinement to bed. There was a pronounced loss of weight and a marked neuromuscular atrophy. Blood pressure was 138/82. Her general examination was normal.

Laboratory Data: Urine was normal except for one plus acetone. Blood examination showed an average normal cell count. Blood Wassermann was negative.

Roentgenographic Examination: Roentgenograms of the esophagus and stomach taken on June 24, 1947, showed the diameter of the esophagus down to the ninth rib posteriorly to be normal. There were two diverticula extending to the right, and posteriorly, just above the cardia. The cardiac canal and fundus of the stomach were within normal limits (Fig. 1).

Operation: On July 8, 1947, after suitable preparation by intravenous fluids, vitamins, blood transfusion, lavage of stomach and esophagus, and intramuscular penicillin, the patient

was operated upon, under intratracheal cyclopropane, ether, and oxygen anesthesia. An incision was made over the eighth intercostal space from the angle of the eighth rib and extending downward over the cartilage of the eighth rib on to the abdominal wall, and then parallel to the outer border of the left rectus muscle to the level of the umbilicus. The peritoneal and pleural cavities were then entered, and the diaphragm was split radially from the costal cartilage to the esophagus, converting the abdominal and pleural cavities into one

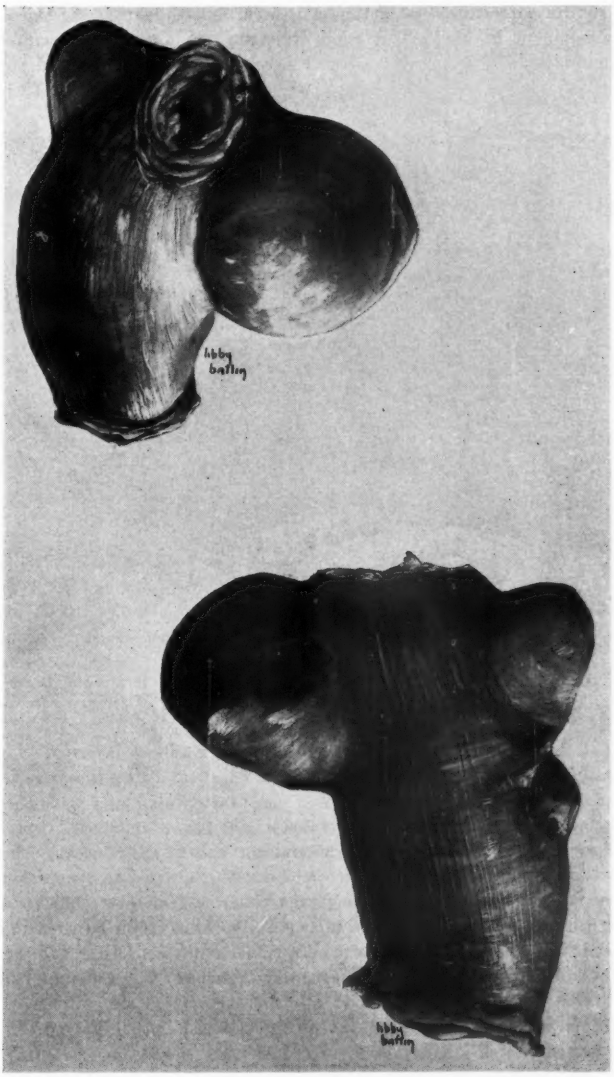

Fig. 2.—Case 1. Drawing of exterior of operative specimen of resected esophagus and diverticula.

large exposure. The left lung was densely adherent to the parietal pleura and to the diaphragm, and this was dissected off. The pleura over the esophagus was then incised from the arch of the aorta down to the diaphragm. The esophagus with the diverticula was then lifted from its bed with necessary hemostasis, care being exercised to avoid injury to the right pleura where the diverticula were adherent. The stomach was then mobilized by first tying off the left gastric vessel near the celiac axis and then separating the attachment of the stomach from the spleen and transverse colon, by ligation of the left gastroepiploic and the vas brevia, with preservation of the epiploic arch, finally ligating the right gastric and the right gastroepiploic arteries. This made it possible to draw the stomach through the split diaphragm into the chest without any degree of tension. The blood supply of the stomach seemed adequate. The distal end of the esophagus was then resected with a portion

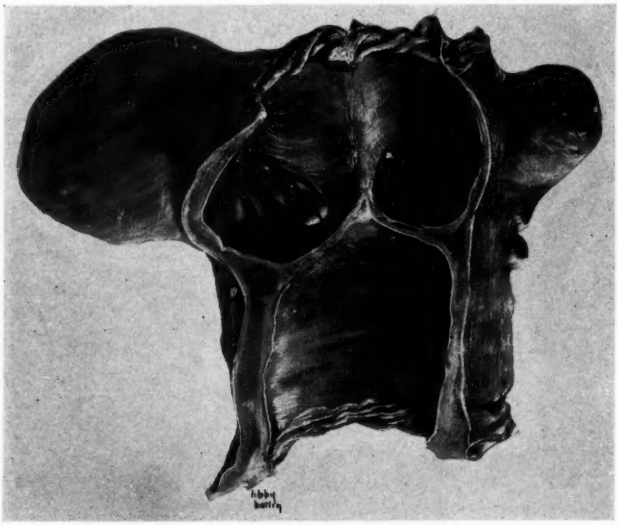

Fig. 3.—Case 1. Drawing of interior of resected esophagus showing probe through lumen of esophagus at the site of septum below diverticula.

of the cardia of the stomach and the opening then closed with two layers of interrupted fine silk. The proximal end of the esophagus was resected about two inches below the arch of the aorta, and well above the diverticula. A 2 cm. oval opening was made in the anterior wall of the stomach, and a terminolateral anastomosis was then effected between the end of the esophagus and the oval opening in the anterior wall of the stomach, using fine interrupted silk sutures in two layers. The stomach was then secured to the parietal pleura to relieve tension on the suture line. The diaphragm after careful suture to the fundus of the stomach was then reconstructed with interrupted silk sutures. Two hundred thousand units of aqueous penicillin were left in the chest, and a catheter was placed through the tenth intercostal space in the midaxillary line for underwater drainage. The chest and the abdominal incision were closed in layers with chromic catgut. Interrupted silk sutures were used for the skin. The patient was given 1000 c.c. of whole blood during the operation, and she withstood the procedure well.

Course: The patient had surprisingly little pain and temperature, considering the extensive surgical exposure. There was no dyspnea at any time. After the third day, the

patient was allowed to swallow some clear fluid, deglutition being uneventful. Increasing amounts of food were gradually allowed, until by the seventh postoperative day the patient was taking a regular diet. She was discharged on the twelfth postoperative day.

The patient has been followed since and has remained well except for continuation of her arthritis. She gained 27 pounds in the first three months after operation. A postoperative gastrointestinal series showed a normal functioning esophagogastrostomy with resection of the lower end of the esophagus, and the fundus of the stomach lying above the diaphragm (Fig. 4).

Fig. 4.—Case 1. Radiograph showing postoperative esophageal gastrostomy at lower third of the esophagus with resection of the lower end of the esophagus, and fundus of the stomach above the diaphragm.

Pathologic Report: The specimen consisted of the lower portion of an esophagus, measuring 6 by 3.5 cm., manifested in a tubelike structure, the cephalad portion of which contained two lateral pouches measuring 4 by 3.5 by 2.5 cm. and 2 by 2 by 2 cm. The openings into these pouches measured 2 by 1.5 cm. in their greatest diameters. The length of the esophagus joining the cardiac end of the stomach extending below the diverticula measured 3.5 cm. On section the inner lining was smooth. A short distance below the ostia of the diverticula there was a septal-like structure traversing the lumen of the esophagus occluding the lumen, except for a small opening measuring 0.5 cm. in diameter. The pathologic diagnosis was diverticula of the esophagus and partial atresia of distal end of the esophagus. (Figs. 2 and 3.)

Comment: From the description of the gross pathology and the study of the illustration (Fig. 3), the mechanics of the formation of these diverticula are

revealed. The lumen of the esophagus was closed by a diaphragm except for an opening about 0.5 cm. wide. Without any previous history of injury or the swallowing of an escharotic, it is difficult to explain the etiology of the stricture. With the repeated attempts at swallowing, the intraesophageal pressure increased, becoming greatest just above the stricture. The weak areas in the esophageal wall finally developed, permitting the herniation of mucosa through a muscle hiatus. These diverticula should therefore be considered of the pulsion type.

CASE 2.—Mr. J. B. (Flower and Fifth Avenue Hospital, No. 4503), aged 49 years, entered the hospital on May 23, 1948, with the chief complaint of choking on food, progressively increasing for the past one and one-half years. The patient began having difficulty in swallowing dry food. He had a feeling of tightness in the throat. The episodes had increased in frequency. No vomiting was present, and there was no excessive weight loss.

Physical Examination was essentially normal except for a blood presure of 180/108.

Laboratory: Urine normal, hemoglobin 102 per cent, red blood corpuscles 6.2 million, white blood corpuscles 10,100, with a normal differential.

Roentgenograms taken May 11, 1948, before entering the hospital, showed a normal chest with normal heart shadow.

The esophagus, as seen fluoroscopically, on routine films, and on spot films, showed the presence of a diverticulum arising in the lower third of the esophagus. It arose from the anterolateral wall. The diverticulum sac measured approximately an inch in diameter. The entrance to the diverticulum was large, and it did not retain barium after the evacuation of the esophagus. The stomach showed no evidence of intrinsic defect.

Course: Because of the increasing symptoms, it was decided to operate upon the patient and remove the diverticulum.

Operation: Under a combination of intratracheal anesthesia with cyclopropane and curare, the chest was opened. The incision was made through the seventh intercostal space, and extended upward along the lateral border of the vertebral column. The downward extension of the incision was through the costal cartilage on to the abdominal wall. The chest was entered through the intercostal incision after sectioning the sixth and seventh ribs at their angles. The pleura overlying the esophagus was incised, and the esophagus with its diverticulum mobilized from its bed. The diverticulum was situated about two inches below the hilum of the lung and projected to the left. It had a broad base measuring about one inch in diameter, with the diverticulum itself measuring a little more than 1½ inches in diameter. It was globular in shape, and apparently had all the coats of the esophagus. The esophagus was mobilized down to the esophageal hiatus. The diaphragm was then incised and the abdominal cavity entered. The proximal half of the stomach was mobilized by ligating the left gastric vessels and gastroepiploic arch, freeing the greater curvature from attachments to the spleen and the splenic colon (ligating the gastric brevia). The stomach was then easily drawn through the diaphragm into the chest. The distal portion of the esophagus was resected, including the diverticulum and an anastomosis was effected between the stomach and the esophagus, terminolateral in type. The original cardiac opening of the stomach was closed, using interrupted black silk. The anastomosis was done in two layers with interrupted black silk. The wound was closed in layers leaving 50 c.c. of penicillin solution containing 100,000 units. One rubber tube drain through a stab wound in the eighth intercostal space posteriorly was used.

The patient received 500 c.c. of blood during the operative procedure, and he withstood the procedure well. The thoracotomy tube was connected to underwater drainage with a small amount of negative pressure. There was a minimal amount of drainage, the tube

being removed on the fourth postoperative day. The temperature never went over 100.6° F., and the patient was started on full liquids on the fourth day and was on soft food on the fifth day, with no difficulty in swallowing. The patient was discharged entirely well on the twelfth postoperative day. Follow-up examinations have found the patient with no complaints, eating all food with no difficulty.

Pathology: Gross: Resected portion of esophagus with diverticulum. Microscopic examination showed leukoplakia with chronic ulceration, chronic inflammation, and some mucosal hyperplasia.

Diagnosis: Diverticulum and ulcer of lower portion of esophagus.

Comment: The operative procedure of resecting the diverticulum or diverticula and the distal portions of the esophagus has never been reported. It is definitely indicated in those patients who would require a diverticulectomy and also require a plastic repair of the esophagus for stricture or cardiospasm. The mobilization of the stomach into the chest and subsequent anastomosis is relatively simple now, so that there should be no hesitation in resecting the pathology completely.

SUMMARY

All cases of epiphrenic diverticula of the esophagus recorded in the literature are reviewed. There were 126 cases reported in the literature. Of these, forty-three, or 33 per cent, were operated upon, with a mortality of 0.9 per cent. The transition of operative technique is discussed, and a new procedure, that of resecting the distal portion of the esophagus and cardia of stomach with intrathoracic esophagogastrostomy, is presented. Two case reports are given which utilized this operative procedure.

It is felt by the authors that this new operative procedure should be reserved for those cases that would not be adequately treated by diverticulectomy; namely, multiple diverticula, diverticula associated with cardiospasm, with esophageal atresia, or with neoplasm.

ADDENDUM

Since this article was submitted, another successful case of diverticulum of the esophagus associated with carcinoma was successfully operated upon.

CASE 3.—Mr. J. C. (Flower-Fifth Avenue Hospital, No. 6044) a white man, aged 63 years, was admitted on June 13, 1951, because of difficulty in swallowing. The patient was first seen on June 11 and gave the following history:

History: For the past three months he had increasing difficulty in swallowing. Passage of soft food was very slow and though he never vomited, he has often felt like it. During the past three weeks, he complained of increasing difficulty in swallowing liquids with occasional regurgitation. Occasionally, he complained of substernal pain which was relieved by regurgitation. He lost at least 10 lbs. in the last three months.

Physical Examination: Patient is an elderly white male presenting a picture of dehydration and loss of weight. Blood pressure 110/80. Except for some external hemorrhoids, general physical examination was negative.

Laboratory Data: Urine examination was negative, except for a trace of albumin. Blood examination showed an average normal red cell count, with a hemoglobin of 75 per cent and W.B.C. 13,000, with normal differential. Blood Wassermann was negative. The blood chemistry was within normal range.

Roentgenographic Examination revealed an esophagus which was moderately dilated, with slight redundancy of the middle third. There was definite delay in passage of the barium through the lower end of the esophagus into the stomach. There was a marked irregular narrowing deformity of the lower end of the esophagus, with a moderate sized diverticulum-like pouch extending to the left of the midline. The possibility of a neoplasm could be ruled out (Fig. 5).

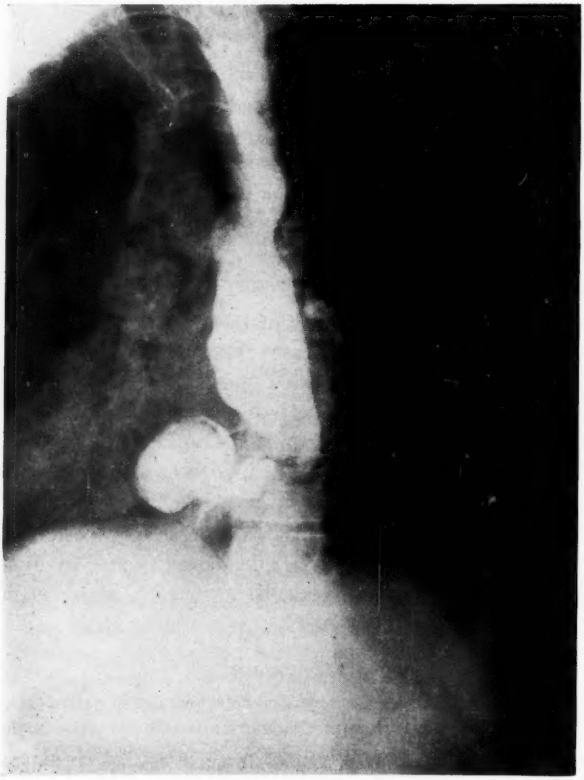

Fig. 5.—Case 3. Preoperative roentgenogram.

Operation: On June 15, 1951, an esophagogastrostomy was performed following the routine described above, resecting the lower half of the esophagus, together with the upper one-fourth of the stomach, including nearly the upper half of the lesser curvature. In performing the anastomosis, the anterior wall of the stomach was folded in below the site of the anastomosis to create a flap. The purpose of this flap was to help check gastric reflux into the esophagus. The anastomosis was about 2 c.c. in diameter when completed.

Course: Considering the magnitude of the operation, the patient had little reaction. He was allowed out of bed on the third postoperative day. There was no dyspnea at any time. The patient was allowed to swallow fluids on the third postoperative day. By the seventh postoperative day, he was on a regular diet. The patient was discharged on the tenth postoperative day. The patient was subsequently seen on September 25. He had no

difficulty in swallowing, was working, and had gained 10 pounds. A postoperative roentgen examination revealed an esophagus normal in width at this time without obstruction to the flow of barium into the stomach. About 25 per cent of the stomach was above the left leaf of the diaphragm (Fig. 6).

Fig. 6.—Case 3. Postoperative roentgenogram (close-up).

Pathologic Report: Specimen consisted of a long mass of esophageal tissue including the cardia and lesser curvature of the stomach. In the mid-portion a 1.5 cm. diverticulum leading into the esophagus was seen. A hard white firm mass, 7 by 4 cm. was seen encircling two-thirds of the esophagus not invading the lumen. Study of the proximal end of the resected esophagus showed almost 1.5 cm. of smooth muscle entirely free of invading carcinoma. At the level of the tumor, however, invading squamous cells had penetrated into the adventitial tissue of the esophagus. Study of the distal or cardiac end of resected specimen showed gastric mucosa and wall free of carcinomatous invasion. In one section the junction of gastric mucosa and squamous epithelium of the esophagus was seen. At this point there was slight invasion of the gastric musculature by the squamous carcinoma.

Gross and Microscopic Diagnosis.—

Esophagus: Epidermoid carcinoma showing good differentiation and invasion of all coats of the wall.

Stomach: No pathologic diagnosis.

Comment: The diverticulum in this case is probably of the pulsion type. As a result of almost complete encirclement of the esophagus, a weakness in the wall had developed resulting in the formation of the diverticulum in response to the increase of intra-esophageal pressure.

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SINGLE LEFT SUPERIOR VENA CAVA, WITH AORTIC COARCTATION, IN AN ADULT

Case Report

F. Norman Brown, M.D.
Ottawa, Canada

THE occurrence of bilateral superior vena cava is a well-recognized anomaly. Sanders,[1] in 1946, found 215 such cases recorded in the medical literature. The existence of a left superior caval trunk, without a corresponding vessel on the right, is much less common. Atwell and Zoltowski,[2] in 1938, listed nineteen previously reported cases, and added one of their own. No report of a similar instance could be located in the English writings since that time.

The case reported here is that of a man who was found at autopsy to have a coarctation of the aorta, in close anatomic relationship to a single left superior vena cava.

CASE REPORT

The patient, a well-developed muscular man of 47 years, who was stated to have been previously in good health, died suddenly and unexpectedly at home. In a complete autopsy, performed twelve hours after death, the significant findings were confined to the cardiovascular system and the lungs.

The heart was hypertrophied weighing 600 grams. This enlargement mainly involved the left ventricle, the myocardium of which was firm and measured 2.8 cm. in thickness. While the mitral, tricuspid, and pulmonary valves were thin and pliable, the aortic cusps were somewhat contracted, sclerotic, and nodular. The coronary arteries showed considerable narrowing by scattered, raised, atheromatous plaques, but there were no areas of complete occlusion. Just beyond the origin of the left subclavian artery there was a coarctation of the aorta. The lumen at the constricted point was 0.5 cm. in diameter. The intimal surfaces in this situation, and the proximal 2 cm. of the left subclavian artery were raised and roughened by yellowish plaques, many containing calcium. In contrast, the intima distal to the coarctation was smooth and the aortic wall elastic. Enlarged internal mammary and anterior intercostal arteries indicated a well-developed collateral circulation. Also of increased size were the first posterior intercostal arteries, arising from the aorta immediately distal to the coarctation.

Formed by the union of the left innominate and the longer, obliquely placed, right innominate vein, was a large left superior vena cava overlying the aortic arch and closely approximated to the groove produced by the coarctation (Fig. 1). This anomalous vein was continuous with a vascular channel contained within the posterior wall of the left atrium, draining into the right atrium. No superior caval trunk was present on the right side.

In addition to these abnormalities of the heart and great vessels, the lungs were heavy, wet and subcrepitant, the left weighing 720 grams and the right 860 grams. The other organs were essentially unremarkable grossly.

Microscopic examination revealed little worthy of mention, aside from congestion and edema of lungs.

COMMENT

Consideration of the normal development of veins from the cardinal system indicates the series of events leading to the establishment of a single superior caval trunk on the left side. According to Arey,[3] during the sixth week of

From the Department of Pathology, University of Ottawa, and the Ottawa General Hospital.

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intrauterine life, the true precardinal veins, located laterally in the segmented portion of the head, drain into the common cardinal veins of each side. Normally, an oblique anastomosis occurs at about the eighth week, draining from the left to the right precardinal. This anastomotic trunk becomes the left innominate vein of the adult and the left precardinal persists merely as part of the highest intercostal vein on that side. The stump of the left common cardinal normally assists in forming the coronary sinus and sometimes the oblique vein of Marshall. It is seen that the superior vena cava is usually formed on the right side by the common cardinal and precardinal veins as far as the intercardinal anastomosis (Fig. 2*A*). In this case, a reversal of the

Fig. 1.—Heart, aortic arch, and left superior vena cava. The latter has been displaced laterally to show the aortic coarctation, over which it lay.

normal development evidently occurred, the superior vena cava being formed by the left common cardinal and precardinal veins and draining into the right atrium through a vascular channel contained within the wall of the left atrium (Fig. 2*B*).

A feature of major interest in this case was the presence of both a left superior vena cava and coarctation of the aorta. The association between aortic coarctation and anomalies of the heart and great vessels is well known. The relationship is so frequent as to suggest to Hamilton and Abbott[4] a significant anatomical complex. In an exhaustive statistical report on 200 cases of coarctation of the aorta in 1928, Abbott[5] found 111 cases in which there were other

cardiac or vascular malformations. However, the persistence of a left superior vena cava was reported in only three cases. In these it is not clear whether the right vena cava was also present. Reifenstein, Levine, and Gross[6] recently reviewed the literature on aortic coarctation since Abbott's publication, collecting 104 cases. They listed fourteen types of cardiovascular anomaly occurring in association with coarctation of the aorta but did not encounter a case of persistent left superior vena cava.

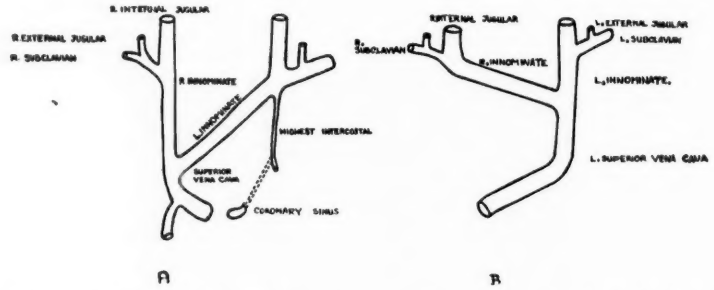

Fig. 2.—*A*, Diagram to show the normal adult arrangement of veins derived from the cardinals (adapted from Arey, L. B.: *Developmental Anatomy*). *B*, Diagram of the arrangement of veins in the present case. There has been a reversal of the normal development, with a resultant left superior vena cava.

Concerning the etiology of coarctation of the aorta, a relationship with the ductus arteriosus, as suggested by the anatomic site of the narrowing, has been widely accepted. According to Hamilton and Abbott, a theory based on this relationship was first proposed by Craigie in 1841. To him it seemed likely that the obliterating potentialities of the ductus arteriosus had for some peculiar reason been extended into the aorta and there given rise to contraction of the wall of that vessel. Hamilton and Abbott believed this explanation (called the Skodaic theory after Skoda who supported it) to be true, at least in part, although the hypothesis of Brunner that in these cases the peculiar tissue of the ductus wall is continued into the wall of the aorta has never been substantiated. It is also of interest that aortic coarctations occur most commonly at a site immediately distal to the origin of the left subclavian artery. It is at this point that the embryonic right arch is detached during the development of the main left dorsal aorta. Here, again, some obliterative process may be proposed as the cause of narrowing.

Despite theories which attempt to relate the development of coarctation to obliterative vascular processes, importance has also been attached to the mechanical effect of traction of the fibrous obliterated ductus arteriosus on the arch of the aorta. Hamilton and Abbott state that this has sometimes been so strong as to produce a tent-shaped aneurysm of the aortic wall in this region. In the present case, the close anatomical relationship of the large left superior vena cava to the coarctation causes speculation as to what effect mechanical pressure might have had on initiating or augmenting the constructive process in the aorta.

In view of the present-day surgical treatment of coarctation of the aorta, any anomaly of possible surgical significance seems worth stressing. Lam,[7] in 1945, recorded a case in which a large anomalous inferior vena cava interfered with an operation for patent ductus arteriosus. It appears likely that, in the case here presented, surgical treatment of the coarctation might well have been impossible. The fact that a persistent single left superior vena cava is rare in association with coarctation has been amply indicated above. Nevertheless, in an individual case, its presence must necessarily be of vital importance in surgical treatment.

It is necessary to give consideration to the cause of death in this case. It seems probable that death was in some way related to the aortic lesion. The persistent left caval trunk could not have had any lethal influence and a complete autopsy failed to reveal any lesion of importance outside the cardiovascular system. Reinfenstein and his co-workers, in 104 cases, found death to be due to rupture of the aorta in 23.1 per cent, to bacterial endocarditis or aortitis in 22.1 per cent, to congestive heart failure in 18.3 per cent, to intracranial causes in 10.6 per cent and to unrelated causes such as pneumonia and carcinoma in 25.9 per cent. In the last category they included three cases in which death was sudden and attributed to coronary arterial disease, and two cases in which death was sudden and unexplained. In the case reported here, the heart was markedly hypertrophied, weighing 600 grams. The coronary arteries showed areas of atheromatous thickening but there were no regions of marked stenosis or occlusion. It seems probable that death in this instance was due to relative myocardial ischemia.

SUMMARY

A case, in a man of 47 years, of a single left-sided superior vena cava associated with coarctation of the aorta is reported. This apparently brings to twenty the number of recorded cases in which a left superior caval trunk occurred without a corresponding vessel on the right side. It would appear that the association of a left superior vena cava with aortic coarctation has been observed on but 3 previous occasions. In these three recorded instances, it is not known whether there was also a right superior vena cava. It is suggested that this type of anomaly may be of importance in the surgery of aortic coarctation.

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CARCINOMA OF THE TRACHEA

FREDERICK G. KERGIN
TORONTO, ONT.

RECENT reports of the laboratory investigation of various methods of bridging gaps in the trachea and bronchi are indicative both of an interest in the treatment of tracheal tumors and the lack of a definitive method of reconstruction which can be applied to human patients with primary tumors of the intrathoracic trachea. Belsey has published a review of the problem which includes a report of two cases in which he partially resected a considerable segment of the intrathoracic trachea and carried out a reconstruction with fascia lata over a framework of stainless steel wire, with brilliant initial success. The only report of a successful initial result after resection of a complete segment of the intrathoracic trachea in a human subject is that of Jarvis, who bridged the gap with a stainless steel tube in the manner evolved by Daniels in experimental work on dogs. Clagett attempted a similar reconstruction, using a tube of polyethylene, but his patient died.

Because primary malignant tumors of the trachea are rare, no one surgeon is likely to have an opportunity to treat more than a very few. For that reason the report of a single case may be justified. The method of reconstruction used in this case failed, but the principle involved appears to be sound; the failure was due to technical details which are capable of correction.

G. E., a white man aged 51 years, was admitted to the medical wards of the Toronto General Hospital on June 30, 1949, with a diagnosis of acute pulmonary edema. For three months he had had a severe cough, productive of mucoid sputum, with marked shortness of breath and orthopnea. On the day before admission he had coughed up a large amount of blood. He had lost forty pounds. He was a chronic alcoholic who for years had had cough with moderate sputum.

The patient was an obese man with a short neck and deep chest. Even in an oxygen tent he showed extreme dyspnea with persisting cyanosis, but no evidence of cardiac failure. Coarse rhonchi were present throughout the chest. He developed clinical and radiographic evidence of bilateral bronchopneumonia with a fever up to 103° F., which did not respond to penicillin, and continued to cough up large amounts of blood-tinged sputum.

Laminagrams (Fig. 1) demonstrated a rounded mass arising from the right side of the trachea just above the right main bronchus and almost completely occluding the lumen of the trachea. A bronchoscopic examination on

From the Department of Surgery, University of Toronto, and the Toronto General Hospital.

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July 25 revealed a mass bulging from the right wall of the lower trachea, and below this the right main bronchus could be seen containing granulation tissue. A biopsy was taken but failed to show tumor. On withdrawing the bronchoscope the trachea became completely obstruced so a gum elastic catheter was passed into the right main bronchus. This was left in place for five days and then removed, and the patient continued to have a fairly adequate airway.

Fig. 1.—Laminagram showing tumor arising from right wall of lower trachea and almost completely obstructing lumen.

At this point the patient was seen by the surgical service. He had bilateral bronchopneumonia, with a temperature of 102° F. There was a persistent substernal wheeze, cough with copious sputum, and he seemed in imminent danger of recurrence of tracheal obstruction and death from asphyxia. It was decided to attempt removal of the tracheal tumor.

On August 5 the patient was anesthetized with pentothal and curare and, using a bronchoscope, an endobronchial catheter was forced past the growth into the left main bronchus, and the anesthetic continued with cyclopropane.

The right chest was opened by resection of the sixth rib. The posterior half of the lower lobe including the superior segment showed consolidation. The azygos vein was divided, and the trachea exposed. On the right side, just above the main bronchus, a tumor could be felt, about 2.5 cm. in length. Adherent to the trachea in this area was a lymph node, 1 cm. in diameter, which was removed and showed no tumor on frozen section. At this point the patient was

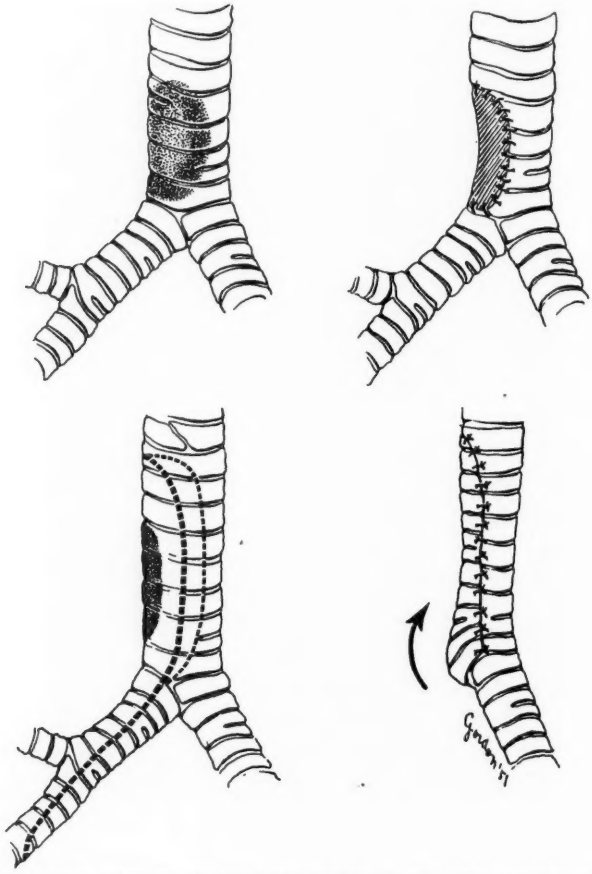

Fig. 2.—The upper diagrams illustrate the position of the original lesion, and the repair of the defect with a patch of pericardium after local excision. The lower diagrams illustrate the treatment of the recurrence and the reconstruction of the trachea using a pedicle graft from the right bronchus.

doing badly. He was very anoxic, the heart had stopped, and had restarted after massage. The tumor was rapidly excised, leaving a defect in the trachea 3 cm. by 1 cm. This was covered by a free graft of pericardium held taut by interrupted sutures of fine silk, and covered by a strip of Gelfoam. The chest was closed with underwater drainage.

The patient made a remarkably good recovery. The bronchopneumonia cleared over the course of five days, and following that the patient had only his usual chronic cough, and a good airway.

Examination of the tissue removed from the trachea revealed a typical squamous-cell carcinoma with many epithelial pearls.

It was obvious that this local procedure could not cure this lesion. Commencing on September 10 a course of roentgen therapy was given, centered on the lower end of the trachea from multiple ports, with a tumor dosage of 3,100 r. units. While this therapy was still being given a further bronchoscopic examination, two months after operation, showed a small area of recurrence, which was confirmed by biopsy. It was decided that a further surgical excision must be attempted.

On November 5 the patient was again anesthetized but immediately went into a state of collapse with systolic blood pressure of 60 mm. A diagnosis of coronary infarction was made, and the operation postponed. This diagnosis was confirmed by electrocardiographic examination. The patient made a good recovery.

On November 25 anesthesia was again induced and a large endobronchial catheter passed into the left main bronchus. The right chest was reopened, the lung freed and the trachea examined. There was considerable inflammatory reaction at the site of the previous operation, but no evidence of tumor outside the trachea. It was decided that because of the proximity of the tumor to the right main bronchus an adequate resection would involve sacrifice of the right lung. The pulmonary artery and veins were divided, and all the hilar structures freed except the bronchus. An incision was then made in the trachea and carried down on to the right main bronchus in such a fashion as to remove two-thirds of the circumference of the trachea for a distance of 5 cm. above the bifurcation, together with the lung and the upper half of the main bronchus, but preserving the lower half of the right main bronchus for a similar distance of 5 cm. In this way a pedicle graft of bronchus was created to correspond to the defect in the trachea, hinged at the carina. It was easily turned upward over the defect in the trachea, fitted it accurately, and was sutured into place with multiple interrupted sutures of fine silk. A wide resection of mediastinal pleura and areolar tissue about the trachea had been done, so no tissue was available to cover the graft. The chest was closed with underwater drainage.

The operation was tolerated well and the patient did extremely well for two days. Air entry into the left lung was good, there was no evidence of tracheal obstruction, and he was able to raise considerable amounts of tenacious mucus. On the third day he suddenly coughed, was unable to clear the mucus and died immediately of asphyxiation. Just as he died a bronchoscope was passed, and it was found that the lower trachea was oval in shape but a 9 mm. bronchoscope was easily passed into the left main bronchus which was completely occluded with thick mucus.

Post-mortem examination confirmed the obstruction of the left main bronchus by a mucous plug. The anterior descending branch of the left coronary

artery was obstructed by organized thrombus, and there was a large healing infarct of the anterior wall of the left ventricle. No residual carcinoma could be demonstrated. The bronchial graft was alive and apparently healing.

DISCUSSION

A large proportion of primary tumors of the trachea occur at or near the lower end so that reconstruction using the right main bronchus may be considered as one of the possibilities. Belsey laid down four characteristics which are essential to a satisfactory method of reconstruction as follows: (1) lateral rigidity; (2) longitudinal elasticity and flexibility; (3) an adequate and airtight lumen; (4) an uninterrupted lining of ciliated columnar epithelium. The method which has been described fulfilled the last three requirements very well but was somewhat deficient in regard to the first. In this case the right half of the cartilaginous portion of the trachea was removed together with the whole membranous portion. The pedicle graft was in itself of normal rigidity but could hinge at the two suture lines, anteriorly and posteriorly, and so assume a scabbard shape. The lumen was adequate for respiration, and accepted a 9 mm. bronchoscope, but probably tended to collapse with cough, and this undoubtedly contributed to the difficulty in raising mucus. Splinting the lumen in a circular shape by the use of wire, or the temporary use of an intracheal tube until healing was sound would not be a difficult addition to the technique.

Both Jarvis and Clagett performed tracheotomy on their patients to permit easy and certain removal of secretions by suction. That was not done in this case, and tracheal suction by intubation through the nose proved difficult and unsatisfactory. It is probable that the patient would have survived if it had been possible to remove secretions efficiently. Since any method of reconstruction is likely to result in both increased secretion and some disturbance of the cough mechanism, a tracheotomy is a simple and wise precaution.

SUMMARY

A case of squamous-cell carcinoma of the lower end of the trachea is reported. As an emergency measure, to overcome tracheal obstruction, the tumor was excised locally and the defect successfully repaired with a patch of pericardium. A later radical resection with reconstruction using a pedicle graft of bronchus ended in failure. The technical errors responsible for failure are discussed.

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BRONCHIAL OBSTRUCTION WITH CHRONIC ATELECTASIS AND PNEUMONITIS DUE TO HILAR LYMPHADENITIS AFTER LOBECTOMY AND LINGULECTOMY

A Case Report

JOHN Y. TEMPLETON, III, M.D.*
PHILADELPHIA, PA.

THE syndrome of chronic atelectasis and pneumonitis most often involving the middle lobe is well known, and has been adequately described in the papers of Graham, Burford, and Mayer,[4] and Paulson and Shaw.[6] That other lobes and segments are sometimes involved is shown by the reports of several surgeons.[1, 3, 5, 6] Clinically, there is usually a rather prolonged history of chronic pulmonary infection with cough, pain, dyspnea, hemoptysis, and wheezing. Atelectasis of the involved pulmonary tissue and sometimes calcified hilar lymph nodes are seen on roentgenograms. Narrowing of the bronchus may be demonstrated by lipiodol studies and bronchoscopy.

At operation most of these patients are found to have bronchial obstruction of varying degree usually secondary to compression of the bronchus by enlarged hilar lymph nodes. This lymph-node enlargement may be caused by infection elsewhere than in the portion of the lung distal to the obstruction. In a few cases, the bronchial obstruction is due to other factors such as foreign body or intrinsic bronchial disease. Brock and associates[2] have described the anatomic peculiarities of the middle-lobe bronchus which apparently account for the relatively frequent involvement of the middle lobe.

The case to be reported here is one in which atelectasis and chronic pneumonitis, developing in the remaining part of the left upper lobe a few weeks after left lower lobe lobectomy and lingulectomy, necessitated removal of the remainder of the left lung.

CASE REPORT

This 8-year-old white boy was admitted to Jefferson Hospital on the service of Dr. Louis H. Clerf. The history was that of chronic suppurative pulmonary disease of five years' duration. Three months prior to admission he had had a severe attack of laryngo-tracheobronchitis after which he had remained hoarse and dyspneic. Upon physical examination, he was observed to be thin, undernourished, and hoarse. An obstructive type of dyspnea markedly limited physical activity. There was slight cyanosis of the fingernails, but no clubbing. His cough was productive of large quantities of purulent sputum. With the direct laryngoscope, there was seen marked edema about the left arytenoid cartilage and redundancy of the overlying mucosa. The bronchoscopist observed much purulent secretion in both bronchi. Increased difficulty in breathing followed the bronchoscopy, and a tracheotomy was performed. A plain roentgenogram of the chest was not abnormal. A bronchogram demon-

From the Department of Surgery, Jefferson Medical College.
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*Fellow American Cancer Society.

strated unilateral saccular bronchiectasis involving all segments of the left lower lobe and both segments of the lingula of the left upper lobe. The remainder of the tracheobronchial tree was well outlined, and appeared normal.

He was transferred to the surgical service, and a left lower lobe lobectomy and lingulectomy was performed without incident. The remainder of the left upper lobe seemed normal except for a few overlying adhesions. There was no unusual enlargement of the hilar lymph nodes. Of possible importance in the light of later events is the fact that after closure the bronchial stumps were reinforced by suturing over them mediastinal tissues and lymph nodes.

His immediate postoperative course was entirely satisfactory. Roentgenograms of the chest on the first, third, and ninth postoperative days showed satisfactory expansion of the remainder of the left upper lobe. The lung parenchyma appeared normal (Fig. 1). He became afebrile quickly, and his sputum was greatly diminished and no longer purulent. He was returned to Dr. Clerf's service for further treatment of his laryngeal lesion and removal of the tracheotomy tube.

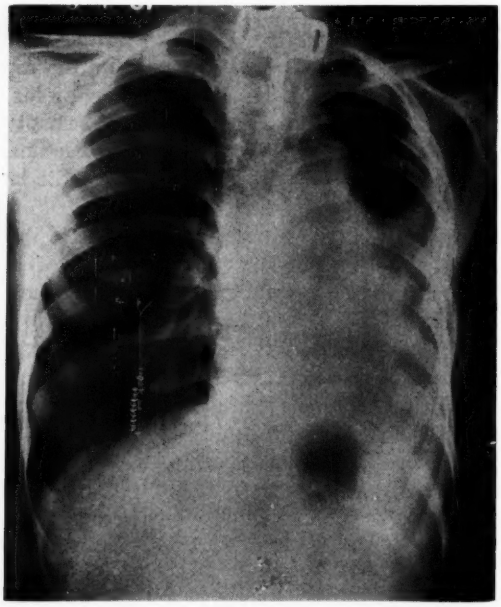

Fig. 1.—Ninth postoperative day. The left upper lobe is well expanded and the parenchyma is clear.

Three weeks after operation, however, his cough again became troublesome and productive of purulent secretions. He developed a septic type of fever. At bronchoscopy a week later, pus was seen coming from the left upper lobe bronchus which appeared distorted. Repeated bronchoscopic examinations during the ensuing four weeks revealed increasing stenosis of the left upper lobe bronchus progressing to the point of almost complete obstruction. At the same time, the purulent secretions increased and his general condition deteriorated. A roentgenogram showed the left hemithorax to be obscured, and the left upper lobe to be only partially aerated (Fig. 2). Instilled lipiodol puddled in the left upper lobe and the narrowing of the bronchus was visualized (Fig. 3).

A second thoracotomy was performed approximately nine weeks after the original operation. There was no free fluid, and the pleural space was obliterated by edematous

adhesions. The remainder of the left upper lobe appeared chronically infected and almost completely atelectatic. Of most interest was a fixed group of enlarged lymph nodes adherent to one another and so situated as to form a constricting ring about the left upper lobe bronchus markedly compressing it. A left upper lobe lobectomy was done and most of the left main bronchus removed. The patient's convalescence from this operation was uneventful, and he is again afebrile and almost free of secretions. Eight weeks after the operation, his general condition is decidedly improved and early removal of the tracheotomy tube is anticipated.

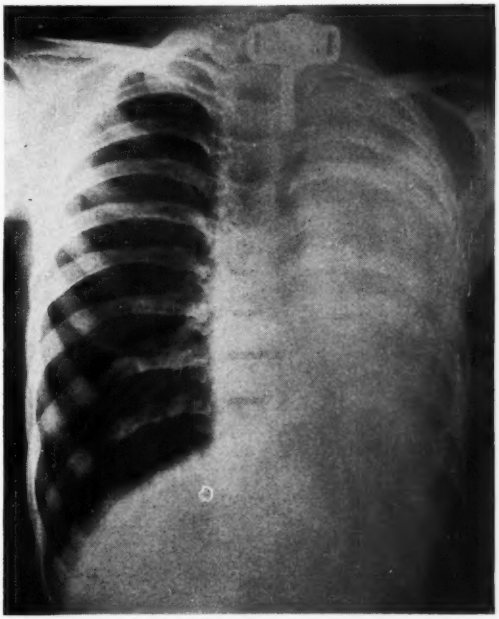

Fig. 2.—Fifty-fifth postoperative day. The left hemithorax is obscured and the left upper lobe partially atelectatic.

Dissection of the operative specimen confirmed the impression gained at operation that the bronchial obstruction was due entirely to compression by the encircling lymph nodes. The two bronchial stumps remaining from the original lobectomy and lingulectomy were well healed, and in on way encroached upon the lumen of the bronchus. There was no intrinsic obstructive lesion of the bronchus at the point of constriction and, after separation of the encircling nodes, the lumen appeared normal. The lobe itself was atelectatic and chronically infected with cylindrical bronchiectatic changes in the bronchi. No abscess cavity was present. The encircling lymph nodes and parenchymal changes are demonstrated in Fig. 4.

DISCUSSION

The case presented here is one in which obstruction of the bronchus to the remaining portion of the left upper lobe after left lower lobe lobectomy and lingulectomy was apparently due to external compression from a ring of enlarged lymph nodes. That the atelectasis and chronic pneumonitis probably followed this obstruction is indicated by the very satisfactory course in the early postoperative period and the absence of any indication of lesions in the

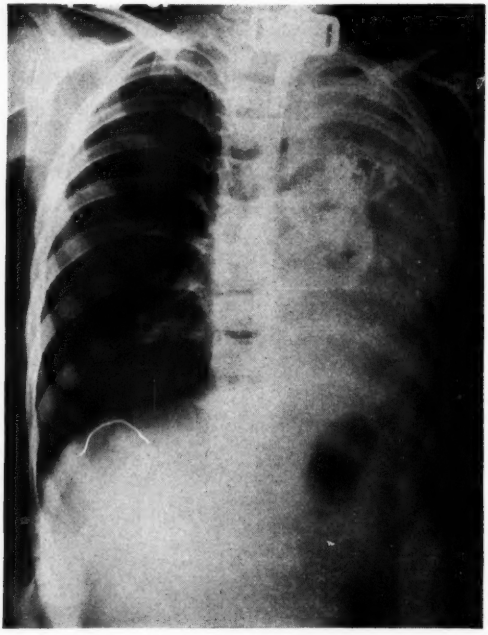

Fig. 3.—Fifty-seventh postoperative day. The lipiodol has pooled in the left upper lobe and the bronchus is narrowed.

Fig. 4.—The operative specimen. Some of the enlarged lymph nodes encircling the left upper lobe bronchus are indicated by arrows. Others lie behind the bronchus.

left upper lobe outside the lingula on the preoperative roentgenograms, at the first operation, or on the roentgenograms during the early postoperative period. The early distortion of the bronchus was not due to displacement of the upper lobe, since peripheral adhesions undivided at the first operation effectively held it in the proper position. The closure of the left lower lobe and lingular bronchi in no way encroached upon the bronchus, nor was there any obstructing lesion of the bronchus itself.

In retrospect, it is probable that the method of covering the bronchial stumps with lymph nodes may have contributed to the formation and fixation of the lymphatic ring. Subsequent enlargement of the nodes secondary to the inflammatory response to the operation could then have caused pressure and obstruction. It is possible that earlier thoracotomy might have permitted relief of the obstruction before serious damage to the pulmonary tissue made excision mandatory.

The possibility of this unusual complication should be borne in mind during the performance of pulmonary lobectomy when tissues to reinforce the bronchial stump are being selected so that the formation of a fixed lymphatic ring about the bronchus may be avoided.

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RETINAL ISCHEMIA WITH UNILATERAL BLINDNESS—A COMPLICATION OCCURRING DURING PULMONARY RESECTION IN THE PRONE POSITION

Report of Two Cases

Harry E. Walkup, M.D., and J. D. Murphy, M.D.
Oteen, N. C.

SINCE the introduction of the prone position for thoracic surgical procedures in 1946, its use has become widespread both in this country and abroad. Many types of apparatus are available for converting the standard operating table for adaptation to this operating position. A special Overholt-Comper Thoracic Table has been made available by the American Sterilizer Company which, in our experience, has been the most satisfactory. In all of these modifications the principle is the same in that head and pectoral supports brace the corresponding anatomic parts. A pelvic support and the body of the table bear the weight of the pelvic girdle and lower extremities. In all instances the head support is horseshoe shaped and is cushioned with rubber. This throws the weight of the head on the frontal bone and the zygomatic processes.

It is the purpose of this paper to present two cases of unilateral blindness following pulmonary resection in the prone position. In each case blindness was attributed to pressure applied to the globe with resultant increased intraocular tension and ultimate ischemia of the retina. This catastrophe was caused by an undetected rotation of the head during the course of the long operative procedure. Direct pressure from the head rest was placed on the globe for a protracted period of time, and loss of vision through retinal destruction resulted.

Case 1.—F. F., a 28-year-old Negro man, who underwent a right pneumonectomy for pulmonary tuberculosis on Nov. 17, 1949. The operation started at 8:30 A.M., and terminated at 11:30 A.M. The operative procedure per se was uncomplicated. On removal of the patient from the Overholt-Comper Table, it was noted that a marked exophthalmus was present in the right eye. An ophthalmologist was immediately consulted and the following report was made:

Ischemia of macular area. Arteries attenuated, but not typical of central artery occlusion. Marked exophthalmus present. Permanent destruction of the retina has occurred.

It was the opinion of this consultant that emergency measures could not alter the status of vision in the right eye. By the tenth postoperative day the exophthalmus had subsided. A careful follow-up during the next few months showed a slight return of light perception, but total blindness persisted to all other stimuli.

Case 2.—C. L., a 27-year-old Negro man, who underwent a right upper lobectomy for pulmonary tuberculosis on May 18, 1951. The operation started at 8:30 A.M., and terminated at 11:50 A.M. No complication occurred during the course of the operative procedure. On removing the patient from the Overholt-Comper Table, it was noted that a marked exophthalmus was present in the right eye, with unusual injection of the scleral vessels. Opthalmologic examination was obtained, and the following report was made:

From the Department of Thoracic Surgery, Veterans Administration Hospital.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are the results of their own study and do not reflect the opinion of the Veterans Administration.

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Patient has complete occlusion of vessels in the right eye. All vessels appear to be empty. The optic disk is very pale. Tension is normal to palpation. There is no hope for return of vision in this eye.

The exophthalmus persisted for approximately one week, gradually subsiding over this period of time. No return of vision occurred on follow-up examination.

In reviewing the literature, no cases of traumatic blindness could be found with an etiologic basis resembling the preceding cases. However, the experimental studies by Kukan, quoted by Puntenney,[1] were encountered during this review, and his findings may throw some light on the mechanism involved in the production of blindness in these cases.

Kukan devised a method of ophthalmodynamometry that consisted of a negative pressure system involving a manometer, sucking disk, and suction pump. With this apparatus positive pressure could be applied to the eyeball when the sucking cup was held in apposition to the globe and negative pressure applied. He demonstrated mathematically that the pressure which sucks the cup simultaneously delivers pressure to the rim of the cup; when the surface area of this sucking portion exceeds that of the rim compression occurs and the intraocular tension rises. After compression has been maintained for a short period of time the aqueous fluid is forced out of the anterior chamber and the retinal blood flow is markedly diminished, with a subsequent drop in the intraocular pressure. It seems plausible that a similar mechanism of action could occur with prolonged constant pressure applied to the globe from the weight of the head compressing the eyeball against the cushioned head rest. A diminished retinal circulation with subsequent destruction of the retinal structures would be a possible sequence of events.

The preceding cases were presented to call attention to a serious complication that can occur with the use of the prone position in thoracic surgery. It is the feeling of the authors that the prevention of this complication will depend on close cooperation between the surgeon and anesthesiologist. It should be the combined duty of the surgeon and anesthesiologist to see that the head is placed properly in the head rest at the beginning of the operative procedure. The anesthesiologist should see that it remains in the proper position until the conclusion of the operation.

SUMMARY

1. Two cases of unilateral blindness are presented occurring during pulmonary excisional surgery with employment of the prone position.

2. A possible mechanism of action is offered based on opthhalmodynamometric studies by Kukan.

3. Cooperation between the surgeon and anesthesiologist is urged in the prevention of this serious and avoidable complication.

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1. Kukan, F.: Zeit. f. Augenh. **90:** 167, 1936. See also Puntenney, Irving: The Effect of Certain Physical and Chemical Stimuli on the Caliber of the Retinal Blood Vessels in Man, Am. J. Ophthalmology **23:** 1113-1122, 1940.

COMBINED STREPTOMYCIN AND TUBERCULIN THERAPY IN EXPERIMENTAL TUBERCULOSIS

H. C. Ballon, M.D., A. Guernon, and M. A. Simon, M.D.
Montreal, Que.

THE investigation of Cairns and associates[1] suggest that the administration of tuberculin (PPD) and streptomycin together might prove beneficial. They treated patients suffering from tuberculous meningitis with tuberculin and streptomycin given intrathecally.

We wish to report the results of streptomycin and tuberculin (PPD) therapy in guinea pigs experimentally infected with tuberculosis. Suboptimal doses of streptomycin were employed. The dose of PPD employed in most instances limited the local tuberculin reaction to an erythematous reaction of slight to moderate intensity.

METHODS

Fifty-six guinea pigs of mixed breed stock, weighing an average 316 Gm., were infected subcutaneously in the right groin region with 0.01 mg. (wet weight) of a 14-day-old transplant of human tubercle bacilli (strain H37rv), grown on egg medium. The inoculum was contained in 0.5 ml. of phosphate buffer solution of pH 7.8. The animals were divided into four groups. There were seven males and seven females in each group. There were a similar number of light colored animals in each group.

Group A: Fourteen guinea pigs were used as controls.

Group B: Fourteen guinea pigs were treated with PPD alone. Treatment was started two weeks following infection. The dose of PPD varied from 0.00001 mg. to 0.001 mg.

Group C: Daily, except Sundays, fourteen guinea pigs received 5 mg. of streptomycin subcutaneously for a period of six weeks. Treatment was started two weeks following infection. By this time the local lesion was well defined, the regional nodes palpable.

Group D: Fourteen guinea pigs were treated with streptomycin and PPD. Treatment was started two weeks following infection. The dose of streptomycin was 5 mg. daily; the dose of PPD varied from 0.00001 mg. to 0.001 mg.

Intracutaneous tuberculin injections were given at three- to four-day intervals. When the erythematous skin reaction occurred, it became evident within twenty-four hours. In most instances the reaction had subsided by seventy-two hours. When the more severe hemorrhagic necrotic type of local reaction developed, the acute phase seemed over within seventy-two hours. Repeated injections gave rise to fresh local responses, but did not seem to alter the appearance of the previous response.

From the Department of Surgery, and the Laboratories of the Jewish General Hospital, Montreal.

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TABLE I. SUMMARY OF MACROSCOPIC TUBERCULOSIS FOUND IN EACH GROUP

ANIMAL GROUP	GUINEA PIG	DEGREE OF MACROSCOPIC TUBERCULOSIS					
					LYMPH NODES		LOCAL LESION
		SPLEEN	LIVER	LUNGS	R.I. ⊙	TB ⊙	
Controls	(1)	+++	+++	++-+++	±	++	+-++
	(2)	+++	+++	++-+++	+	++	++
	3	+++	+++	++	+	++	+++
	4	+-++	++-+++	+	+	+	++-+++
	5	++	++	++	±	++	++
	6	++-+++	++-+++	+-++	±	+-++	+-++
	7	++-+++	++	+	+-++	+-++	+
	8	+++	+++	+	+	+	+
	9	+-++	-	-	±	+	+
	10	++-+++	++-+++	+-++	+-++	+-++	+
	11	+++	++-+++	+-++	++	++	+
	12	±	+	+-++	+	+-++	++
	13	+++	+-++	±	+	+-++	+
	14	+-++	++-+++	+	+	++	+++
Tuberculin alone	(1)	++	++-+++	+-++	+	+	++
	(2)	+++-+++	+++	++-+++	±	±	++
	(3)	+++	+++	++	+	+	++
	(4)	+++	+++	±	+	+-++	+++
	(5)	+++	++-+++	±	+	+	++
	6	++-+++	+++	++-+++	+	+-++	+++
	7	+++	+++	±	+	+-++	++
	8	+++	++	++-+++	+	+-++	++
	9	++	++	±	±	±	+
	10	++-+++	++	+	+	+-++	++
	11	+-++	++	-	+	+-++	++
	12	++-+++	++	++	+	+	+-++
	13	++	++	+-++	+	+	+-++
	14	±	+	±	+	++	+
Streptomycin alone	1	-	±	±	+	±	±
	2	+	±	-	±	+	±
	3	-	-	-	±	±	±
	4	+-++	-	+	+	±	-
	5	-	-	-	±	-	-
	6	±	++	-	±	±	±
	7	-	-	-	±	±	±
	8	-	±	-	+	-	-
	9	±	-	+	±	±	-
	10	±	-	-	±	±	+
	11	±	±	±	+	-	-
	12	+	+	-	+	±	±
	13	±	-	-	±	±	±
	14	±	-	-	±	-	±
Streptomycin and tuberculin	1	-	-	-	±	±	±
	2	-	-	-	+	-	-
	3	-	-	-	±	-	
	4	-	-	-	+	-	±
	5	-	-	-	±	±	±
	6	-	±	-	+	±	+
	7	±	-	±	±	±	±
	8	±	-	-	+	±	-
	9	-	-	-	+	-	-
	10	±	±	-	±	-	±
	11	-	±	-	±	±	±
	12	-	-	±	±	±	-
	13	-	-	-	±	-	-
	14	-	-	-	+	-	-

- = none or questionable tuberculosis.
± = slight.
+ = Moderate.
++ = extensive and +++ = very extensive tuberculosis involvement.
( ) = died during experiment.
R.I. ⊙ = regional inguinal nodes.
T.B. ⊙ = tracheobronchial nodes.

All injections were contained in a volume of 0.2 ml. Streptomycin was dissolved and diluted in sterile distilled water. PPD tablets of 0.05 mg. strength were suspended in sterile phosphate buffer solutions of pH 7.4.

All animals which survived were sacrificed eight weeks after infection. At necropsy the degrees of gross involvement of the local lesions, regional inguinal and tracheobronchial nodes, the spleen, liver, and lungs were noted.

The diet of all animals consisted of calf grower meal, carrots, and lettuce, (about 40 Gm. of the latter per guinea pig per day); a large bowl of cool tap water was provided for each cage for a period of two hours every morning around 8:00 A.M. The injections were given at 10:00 A.M. Lettuce and carrots were served in late afternoon; calf grower meal, consisting mainly of mixed cereals, was available at all times except during the drinking period early in the morning. The temperature in the animal house was kept at about 72° F.

RESULTS

A quantitative grading of the macroscopic tuberculous disease in each animal of the four groups has been listed in Table I.

A. Control Animals.—All but two of the fourteen control animals had generalized tuberculosis. Two animals died of generalized tuberculosis during the experiment. Towards the end of the experiment the majority were beginning to lose weight (Fig. 1).

A tuberculin skin test performed one week before these animals were sacrificed showed a moderately intense reaction to 0.0001 mg. of PPD. Four animals showed the hemorrhagic necrotic type of reaction (Table II).

B. Tuberculin Treated Animals.—Thirteen of fourteen guinea pigs treated with tuberculin alone had generalized tuberculosis. Five guinea pigs in this group died with generalized disease during the experiment. Most animals showed a significant loss in weight during the last two weeks of the experiment. The skin reaction varied greatly, especially during the last three weeks. It was absent frequently; less frequently it showed hemorrhagic necrosis or the erythematous type of reaction (Table III).

C. Streptomycin Treated Animals.—In this group, the local lesions, when present, were small. The regional inguinal lymph nodes were usually small, minimally involved; the tracheobronchial nodes to a lesser degree. The spleen

TABLE II. TUBERCULIN REACTION IN GUINEA PIGS TREATED WITH STREPTOMYCIN ALONE AND IN CONTROL UNTREATED ANIMALS

NO. OF ANIMALS	REACTION NOTED IN INCREASING ORDER OF INTENSITY													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Streptomycin	–	–	–	–	–	–	±	±	±	±	±	±	+	+
Controls	⊙	⊙	±	±	+	+	+	+	+	+	(+)	(+)	(+)	(+)

Test dose: 0.0001 mg.; animals tested seven weeks following infection.
⊙ 2 animals died some days before they could be tuberculin tested.
– = no reaction.
± = area of erythema less than 10 mm. in diameter.
+ = area of erythema 10 mm. and more in diameter.
(+) = area of necrosis or hemorrhagic necrosis.

was moderately diseased in three animals, slightly in six, and free of gross lesions in five. The liver was extensively affected in one animal, moderately in another, slightly in four, and free of gross lesions in eight. The lungs were grossly free in ten animals, moderately involved in two, and slightly in two. A constant gain in weight was observed in animals of this group.

Tuberculin skin tests were performed on these animals a week before they were sacrificed. Eight reacted mildly, six failed to react to 0.0001 mg. of PPD (Table II).

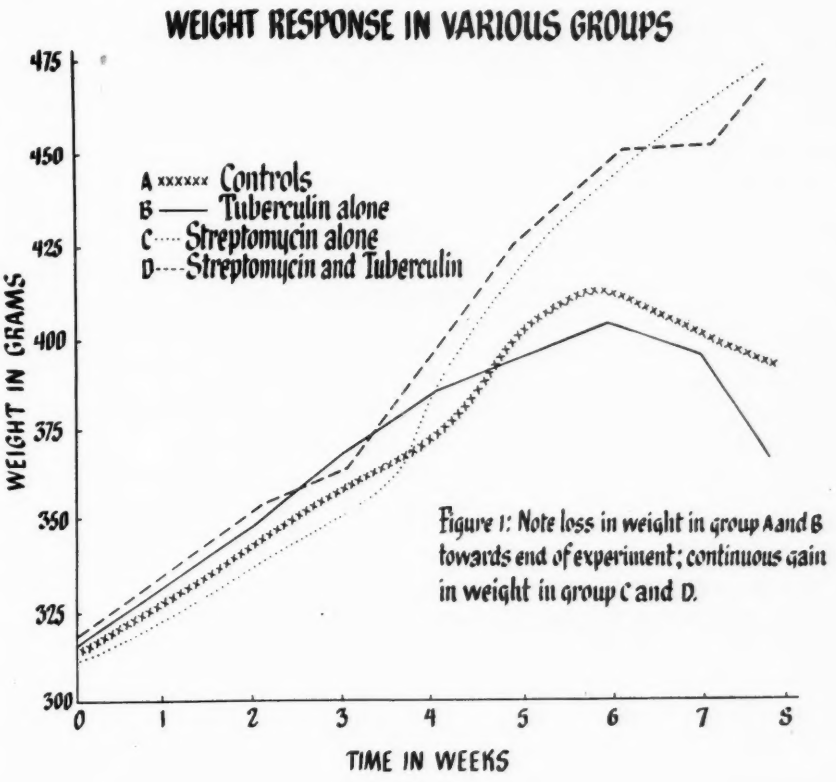

Fig. 1.

D. Streptomycin and Tuberculin Treated Animals.—Eight animals treated with streptomycin and tuberculin failed to show gross lesions. In six, the degree of macroscopic tuberculosis was slight. The findings in the local lesions, regional and tracheobronchial lymph nodes were similar to those noted in the streptomycin treated group. Constant gain in weight was observed. A positive skin reaction of slight to moderate intensity was generally noted in these animals following treatment (Table IV).

TABLE III. DEGREE OF TUBERCULIN REACTION IN GUINEA PIGS TREATED WITH PPD ALONE

DOSE OF PPD (MG.)	DAYS AFTER INFECTION	REACTION NOTED IN INCREASING ORDER OF INTENSITY													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.00001	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.0001	18	–	–	–	±	±	±	+	+	+	+	+	+	+	+
0.0002	21	–	–	–	±	±	+	+	+	+	+	+	+	+	+
0.0002	24	–	–	–	–	–	–	–	–	±	±	±	+	+	+
0.0005	27	–	–	–	–	±	±	±	±	+	+	+	+	+	+
0.0005	31	–	–	–	–	–	–	±	±	±	±	+	+	+	+
0.0005	35	–	–	–	–	±	±	±	±	(±)	+	+	(+)	(+)	(+)
0.0002	38	–	–	–	–	–	–	–	–	–	–	–	–	±	±
0.0005	42	⊙	–	–	–	–	–	–	–	–	±	(±)	(+)	(+)	(+)
0.001	45	⊙	⊙	–	–	–	–	–	–	–	±	±	(+)	(+)	(+)
0.001	49	⊙	⊙	⊙	⊙	⊙	±	±	+	(+)	(+)	(+)	(+)	(+)	(+)
0.0005	52	⊙	⊙	⊙	⊙	⊙	–	–	–	–	–	±	±	+	(+)

– = no reaction.
± = area of erythema less than 10 mm. in diameter.
+ = area of erythema 10 mm. and more in diameter.
(+) = area of necrosis or hemorrhagic necrosis.
⊙ = died.

TABLE IV. INTENSITY OF TUBERCULIN REACTION IN GUINEA PIGS TREATED WITH STREPTOMYCIN AND PPD

DOSE OF PPD (MG.)	DAYS AFTER INFECTION	REACTION NOTED IN INCREASING ORDER OF INTENSITY													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.00001	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.0001	18	–	–	–	–	±	±	+	+	+	+	+	+	+	+
0.0002	21	–	–	±	±	+	+	+	+	+	+	+	+	+	+
0.0002	24	–	–	–	–	–	–	–	±	±	±	+	+	+	+
0.0005	27	±	±	±	+	+	+	+	+	+	+	+	+	+	+
0.0005	31	±	±	±	±	±	+	+	+	+	+	+	+	+	+
0.0005	35	±	±	±	±	+	+	+	+	+	+	+	+	+	(+)
0.0002	38	–	–	±	±	±	±	±	+	+	+	+	+	+	+
0.0005	42	–	±	±	±	±	±	±	±	±	+	+	+	+	+
0.001	45	–	±	±	±	±	±	±	±	±	+	+	+	+	+
0.001	49	±	±	±	±	+	+	+	+	+	+	+	+	(+)	(+)
0.0005	52	–	±	±	±	±	±	+	+	+	+	+	+	+	+

– = no reaction.
± = area of erythema less than 10 mm. in diameter.
+ = area of erythema 10 mm. and more in diameter.
(+) = area of necrosis or hemorrhagic necrosis.
(=) Treatment with Streptomycin started fourteen days after infection; dose of 5 mg. daily for six weeks.

DISCUSSION

Control animals and those treated with tuberculin alone, with but few exceptions, showed similar generalized types of disease consistent with a moderately large infective dose of tubercle bacilli.

Animals treated with tuberculin alone showed a higher mortality and a greater loss in weight than did the controls. It appeared that under the conditions of our experiment, treatment with PPD alone proved harmful to tuberculous guinea pigs.

Our findings in animals treated with streptomycin alone correspond to those reported by other workers. The organs of many guinea pigs revealed

tuberculosis in the gross; but these lesions were of a minimal nature when compared with the extensive disease found in either the untreated controls or the tuberculin treated animals.

Animals treated with both streptomycin and tuberculin showed distinctly less tuberculosis than did those treated with streptomycin alone.

Independent objective microscopic study and grading of the tissues of streptomycin and streptomycin plus tuberculin treated animals revealed that those animals which received combined therapy developed significantly less tuberculosis than did the animals which received streptomycin alone. The spleens of the streptomycin treated guinea pigs showed more tubercles and slightly more caseation than did the spleens of streptomycin and PPD treated guinea pigs. The livers of streptomycin treated animals also showed more changes. Tubercle bacilli were demonstrated in some of the livers of streptomycin treated animals but none were observed in the streptomycin and PPD treated animals. The inflammatory reaction in the lungs of the streptomycin treated animals was more marked than it was in the lungs of the streptomycin and PPD treated animals.

The failure of a number of guinea pigs treated with streptomycin alone to react to tuberculin was first noted by Feldman and co-workers.[2] Six of our streptomycin treated animals did not react to 0.0001 mg. of PPD, while the remaining eight animals reacted only mildly when tested seven weeks after infection. The majority of our control untreated guinea pigs, also tested once on the same day with a similar dose of PPD, gave strongly positive skin reactions. Four exhibited hemorrhagic necrotic reactions.

In the group of fourteen guinea pigs treated with PPD only, a hemorrhagic necrotic reaction was a not infrequent finding during the last three weeks of the experiment. The same animal might develop two and even three such reactions at different sites upon successive testing at intervals of a few days. The erythematous type of reaction occurred irregularly during this period. In this group a complete lack of skin sensitivity was observed very often. The two extremes of no reaction or intense reaction on testing with a given dose on the same day was frequently noted. (See Table III for treatment doses.) A tendency towards tuberculin desensitization may have developed in some of these guinea pigs. Treatment with PPD probably hastened the death of some animals in this group. Loss in weight was greater in these animals than in the untreated controls.

The tuberculin reaction in the streptomycin-PPD treated group, in general, was positive and constant during the last four weeks of treatment. Progress towards desensitization was not apparent in these animals. Thus the type and extent of skin response elicited by 0.0005 mg. on the twenty-seventh or thirty-first day following infection was practically the same as that obtained with the same dose on the fifty-second day. (See Table IV for treatment doses.) Of 168 treatment doses given to guinea pigs of this group, in only three instances could the local intracutaneous skin reaction be classified as more than moderately erythematous; necrosis occurred twice and hemorrhagic necrosis once.

SUMMARY

Guinea pigs infected with 0.01 mg. of tubercle bacilli (human strain H37rv), were treated with either tuberculin, streptomycin, or a combination of streptomycin and tuberculin (PPD).

Under the conditions of our experiments, treatment with tuberculin (PPD) alone proved harmful.

Guinea pigs treated with streptomycin plus tuberculin developed significantly less tuberculosis than those treated with streptomycin alone.

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SIMPLE CARDIAC DEFIBRILLATOR*

GEORGE L. BIRNBAUM, M.D.
AMARILLO, TEXAS

A SIMPLE portable and inexpensive defibrillator, essential in any operating room, can be built for less than ten dollars of material. The parts required are: one ammeter 0 to 5 amperes, one fixed resistor 50 watts, one variable resistor 50 watts, and one ordinary push-button switch. The shocking electrodes for the heart are copper plates 3½ inches in diameter set in "plexiglass" plastic handles† 9½ inches long and ¾ inch in diameter.‡ The copper plates can be covered with a fine chamois felt, if desired, to avoid overheating the heart.

The housing for the apparatus, less electric cords and electrodes, weighs 1 pound, 14 ounces (galvanized iron with plastic top). Its dimensions are: length 7 inches, width 4½ inches, height 3¼ inches.

The defibrillator utilizes ordinary 110 volt alternating house current, and is designed for use in cases of ventricular fibrillation associated with cardiac arrest occurring in the operating room. Its general construction and specific use has been described by Beck.§ The chest may already be open for a thoracic operation. If not, an incision up to 10 inches, extending laterally from the sternum in the fourth or fifth interspace, is *quickly* made by the surgeon.

Beck states that when there is no palpable pulse, no blood pressure, and no respiration, no time should be wasted. Cardiac resuscitation must be started at once. He lists the following "*DON'TS*" if certain failure is to be avoided:

1. *Don't* listen for a faint heart sound.
2. *Don't* wait for an electrocardiogram.
3. *Don't* inject epinephrine through the chest wall into the heart.
4. *Don't* dilate the rectal sphincter.
5. *Don't* give mechanical respiration by compression of the chest.
6. *Don't* give a blood transfusion.
7. *Don't* give an intra-arterial transfusion.

Beck states that the surgeon and anesthetist have only three to five minutes to expose the heart and, by cardiac massage and oxygenation of the lungs, prevent irreversible cerebral anemia. After the interspace is incised, the fourth and fifth

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From the Surgical Service, Veterans Administration Hospital.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the author are the result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

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*Developed in the Engineering Division, Veterans Administration Hospital, Amarillo, Texas, by Mr. George A. Welch, Engineer Officer, Mr. Leland B. Roper, and Mr. Fred H. Kelly, in accordance with the general instructions of TB 10-65, July 18, 1950.

†The handles are conveniently constructed from two halves cemented together around the wiring.

‡A set of children's electrodes, smaller in diameter, should also be available.

§Beck, C. S. Treatment of Cardiac Arrest. Veterans Administration Technical Bulletin, TB 10-65, July 18, 1950.

cartilages are cut, the wound retracted with a self-retaining retractor, and the heart massaged at a rate of 60 to 70 per minute. The surgeon determines the most effective method of massage. The heart can be rhythmically compressed against the sternum with one hand; or it can be compressed between the palm and fingers of one hand posteriorly and the fingers of the other hand anteriorly. It may be necessary to incise widely the pericardium if the latter mechanically interferes with effective cardiac compression. If rhythmic heart contraction

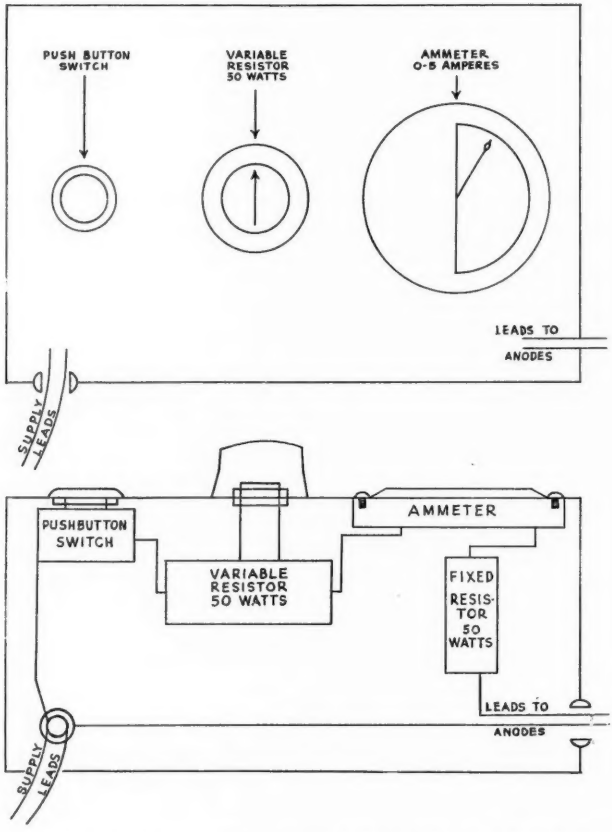

Fig. 1.—*Top*, plan of defibrillator panel as shown, left to right, push-button switch, variable resistor knob, and ammeter. *Bottom*, side view of parts wired in series.

is not restored in a reasonable time, ordinarily a few minutes, the pericardium must now be incised if this has not been done previously, to observe whether the heart is in asystole or fibrillation.

If the heart is in ventricular asystole, injection of 5 to 10 c.c. of 1:10,000 epinephrine into the cavity of the right auricle or ventricle, plus massage, may restore the heart beat. Up to five injections of epinephrine can be given at

intervals of three to five minutes (Beck). Failure to restore the beat indicates faulty lung aeration, faulty heart massage, or heart disease. Epinephrine increases heart tone, but is generally considered to predispose to ventricular fibrillation.

If, on the other hand, the heart is already in or should go into ventricular fibrillation, procaine is used to reduce the irritability of the heart. Procaine reduces heart tone, and therefore not over 5 c.c. of 1 or 2 per cent solution is used per injection. This amount of procaine is injected into the cavity of the right auricle or ventricle, and the heart massaged in order to distribute the drug

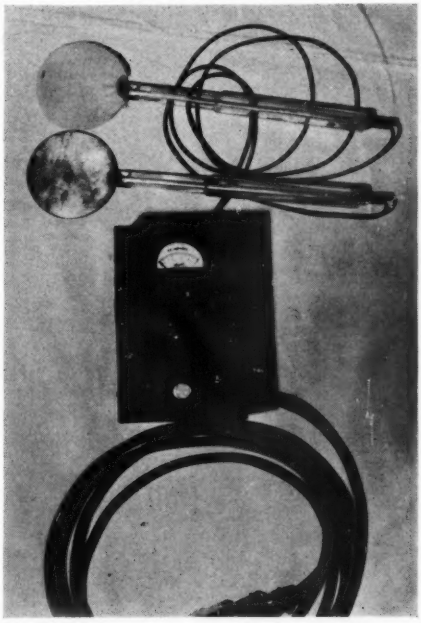

Fig. 2.—Top view of assembled defibrillator. The cords to plastic handle plug in and out for convenience.

From *top* to *bottom*, ammeter, knob for variable resistor, push-button switch. Apparatus delivers a flow of 1 to 1.5 amperes of current, and uses 110 volt alternating current. A quick flip of the finger on the push button will insure current flow for only the required 1/5 to 1/10 of a second.

through the coronary circulation. The defibrillator electrodes are then placed in contact with each side of the heart, as far apart as possible, and by means of a quick flip of the push-button switch, 1 to 1.5 amperes of current are sent through the heart for approximately one-fifth of a second. During this brief period of electric shock the muscle fibers are contracted. When the finger is released from the push button and the current broken, the ventricles may be in asystole or may again fibrillate. If asystole is present, epinephrine and massage are used as described above. If ventricular fibrillation is present, procaine plus massage are used as described above. If fibrillation persists after two electric shocks, no

more procaine is used, but massage is continued and shock may be tried a few more times. Beck states that in his experience epinephrine, although usually contraindicated in fibrillation, can still be cautiously administered in the presence of persistent ventricular fibrillation; it can "supply the spark that starts the beat after the next shock."

At all times—before, during, and after resuscitation of the heart—ample oxygenation of the lungs must be insured by adequate rhythmic inflation of the lungs with oxygen, through an intratracheal tube inserted at the earliest possible moment. *Rhythmic adequate inflation and deflation* of the lungs is paramount to insure proper oxygenation of the blood and release of carbon dioxide out of the blood. In a closed system, carbon dioxide is absorbed by fresh soda lime.

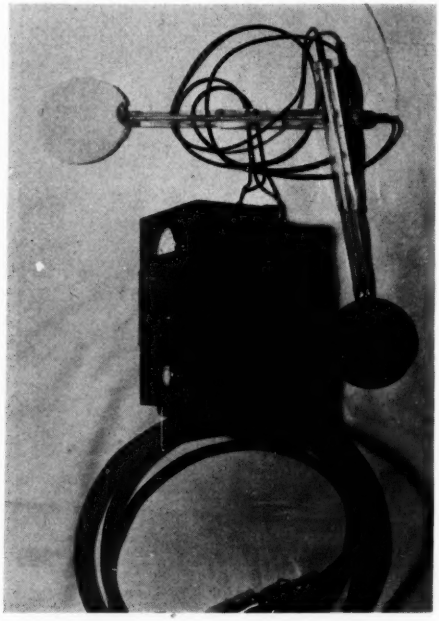

Fig. 3.—Oblique view of assembled defibrillator.

It may take 1 to 2 hours to restore the heart beat; the heart muscle must look pink throughout this period. A mechanical resuscitator is advisable for prolonged pulmonary ventilation; for shorter periods rhythmic compression of the anesthetic bag is usually practiced.

After cardiac resuscitation is achieved the pericardium is loosely closed with sutures, the chest wall tightly closed and the pneumothorax removed by suction through a catheter. Intravenous fluids may now be given for falling blood pressure. Mechanical resuscitation is given until spontaneous respiration is restored. The intratracheal tube is left in place until adequate spontaneous respiration is assured.

Beck's adage *"The beat can be restored in any normal heart"* should encourage the surgeon and anesthetist and discourage despair.

ADDENDA

Since the preparation of this article, the writer has become aware that some have advocated the insertion in the defibrillation unit of an isolation transformer. While this may reduce to some extent the hazard of electric shock to personnel working near the patient, it will not eliminate it. The chief feature of the isolation transformer is to reduce the incidence of fuse blowing. Care to avoid contact of the copper electrodes is necessary to avoid blowing a fuse. Surgeons, anesthetists or other personnel who are or may come into contact with the patient or operating table should wear rubber gloves (preferably two pairs as a precaution against accidental perforation) and avoid grounding themselves by standing on a wooden platform or other nonconductor.

Kay and Blalock found 10 per cent calcium chloride solution lifesaving in the treatment of spontaneous or postdefibrillation cardiac standstill. During operations for congenital heart disease in children, where 0.5 c.c. of 1 to 1,000 epinephrine injected into the left ventricular cavity failed to restore the heart beat, 2 to 4 c.c. of 10 per cent calcium chloride injected into this chamber produced dramatic restoration. Injection into the left ventricular cavity, plus massage, insures the passage of calcium chloride into the coronary arteries and is the preferred method. However, if the left ventricle is inaccessible, any other heart chamber may be used.

Calcium chloride is also valuable to *prevent* ventricular standstill in a heart with weak contractions. The calcium ion appears to act on the ventricular muscle, increasing its excitability and contractility. This effect resembles the accelerator stimulation of epinephrine and the muscular stimulation of digitalis. Calcium chloride solution should therefore be ready and available as part of the resuscitation armamentarium, in the event that epinephrine is ineffectual.

(Kay, J. H., and Blalock, A.: "The Use of Calcium Chloride in the Treatment of Cardiac Arrest in Patients," *Surg., Gynec. & Obst.* 93: 97, 1951.)

SURGICAL TREATMENT OF MULTIPLE ARTERIOVENOUS FISTULAS IN THE RIGHT LUNG IN A PATIENT HAVING UNDERGONE A LEFT PNEUMONECTOMY SEVEN YEARS EARLIER FOR THE SAME DISEASE

BERNARD C. CHARBON, M.D., WILLIAM E. ADAMS, M.D., AND RALPH F. CARLSON, M.D.
CHICAGO, ILL.

ARTERIOVENOUS fistulas of the lung is a relatively rare condition that is being reported with increasing frequency. The case we are reporting here was reported originally in 1944[1] and was the fifth case in the literature at that time. By 1949, however, Yater and associates[2] were able to tabulate forty-three cases, and added two new ones. Since that time reports of several more of these cases have appeared in the literature. An excellent review of the literature is given by Antonio Giampalmo.[3]

A 24-year-old white male welder was admitted to the University of Chicago Clinics on Jan. 24, 1943, complaining of frequent nosebleeds and colds for the last two or three years. He also had marked cyanosis with clubbing of the fingers and toes (Fig. 1, *A*). These findings were first noted shortly after an attack of influenza at the age of six years. Throughout 1941 and 1942 he had been inconvenienced by a mildly productive cough, which was aggravated when he was lying on the left side. He had worked as a farm laborer prior to 1942, and had never been incapacitated by his physical condition.

The family history showed that the patient's father had blue spots on his lips, and had been subject to numerous nosebleeds. Roentgenograms of the father's chest had revealed some shadows. Other male ancestors in the family were also reputed to have nosebleeds and blue spots on their lips. One of the patient's sisters died suddenly at an early age, and another one was said by the patient to be "blue," but she has not been seen by us.

At the time of admission in 1943, the red blood cells numbered 7,200,000 per cubic millimeter, and the hemoglobin content was 23 Gm. per hundred cubic centimeters. The arterial oxygen saturation was 71 per cent (van Slyke). Roentgenograms of the patient's chest (Fig. 1, *B*) showed a lobulated, moderately opaque area covering about 25 cm.^{2} located between the left seventh and ninth ribs posteriorly. A second similar opacity 1 cm. in diameter was seen in the midaxillary line at the level of the right sixth rib. The clinical diagnosis was cavernous hemangioma of the left lung. As a result of this study it was thought at that time that the best treatment would be a left pneumonectomy. This operation was performed by one of us (W. E. A.) on Feb. 11, 1943. The pathologic diagnosis was multiple arteriovenous fistulas of the left lung (Fig. 1, *C* and *D*).

From the Department of Surgery of the University of Chicago.
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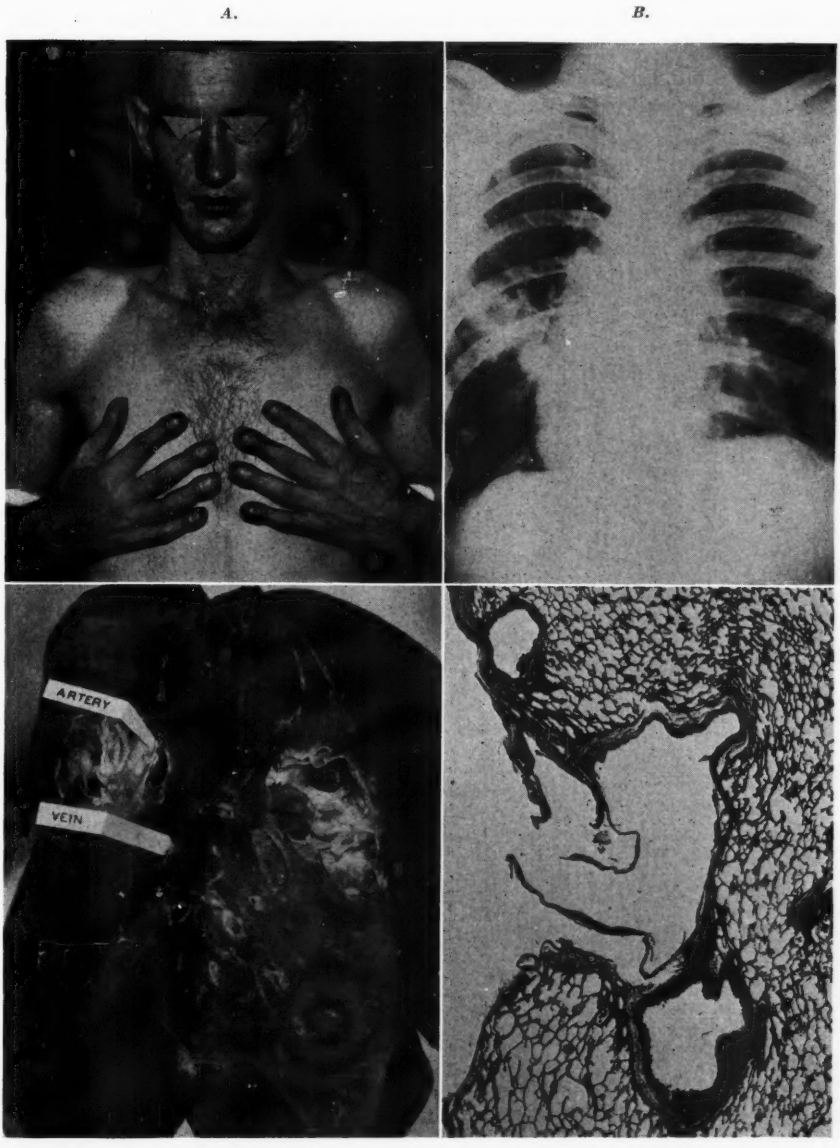

Fig. 1.—*A*, Patient before first operation; note marked clubbing of the fingers. (From Adams et al.: *Arch. Surg.*, **49**: 51-58, 1944.) *B*, Roentgenogram before first operation, showing large irregular opacity in left lung and small (1 cm.) opacity near chest wall of right lung field. (From Adams et al.: *Arch. Surg.*, **49**: 51-58, 1944.) *C*, Gross specimen of left lung: note large aneurysm with arterial and venous communications. (From Adams et al.: *Arch. Surg.*, **49**: 51-58, 1944.) *D*, Microscopic section of portion of fistula. (From Adams et al.: *Arch. Surg.*, **49**: 51-58, 1944.)

The patient's condition improved considerably following this surgery. His cyanosis largely disappeared. Upon discharge three weeks after operation his red blood count had fallen to 5,400,000, with a hemoglobin of 17.5 Gm. Two months later he started working again. Nine months following surgery his red blood count was 5,050,000, the hemoglobin 15.7 Gm.

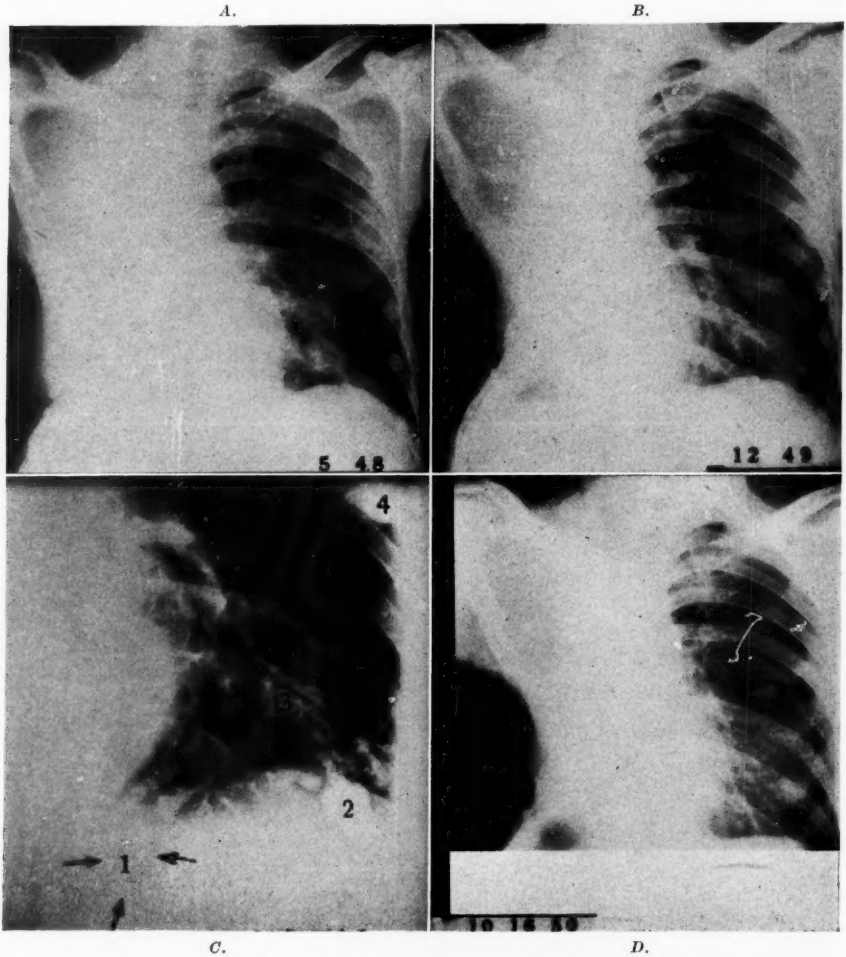

Fig. 2.—*A*, Roentgenogram after thoracoplasty. *B*, Roentgenogram just prior to second operation. *C*, Angiogram. Note the four fistulas filled with contrast material. *D*, Roentgenogram after last operation.

In 1945 a bronchopleural fistula with empyema was diagnosed; however, the patient did not return again until 1948. He then underwent a left thoracoplasty for his empyema. After this operation the patient felt well and continued to work as a farmer and welder. The red count at this time, however,

had risen to 5,900,000, with a hemoglobin of 21 Gm. A chest roentgenogram (Fig. 2, *A* and *B*) showed some increase in the size of the right pulmonary lesion.

Fluoroscopy in 1949 showed the appearance of a new lesion in the lower right lung field. In October, 1949, pulmonary angiograms (Fig. 2, *C*) were made which revealed four cavernous spaces in the lower half of the right chest, the appearance of which was compatible with arteriovenous fistulas. Physical examination in February, 1950, revealed a well-developed, somewhat thin white man with marked cyanosis. Blood pressure was 125/80; pulse, 80; respiration, 22; temperature, 37° C. The lips showed some small hemangiomas. The left chest wall was partially collapsed. No bruit was heard over the right lung field. Except for the marked clubbing of the fingers and toes, no abnormalities were found in the extremities; urinalysis was negative. The blood count showed 7,900 white blood cells, with a normal differential. Hemoglobin was 22 Gm., the red blood cells 7,190,000, and the hematocrit 75 per cent. Arterial oxygen saturation was 69 per cent. Vital capacity was 1,100 cubic centimeter.

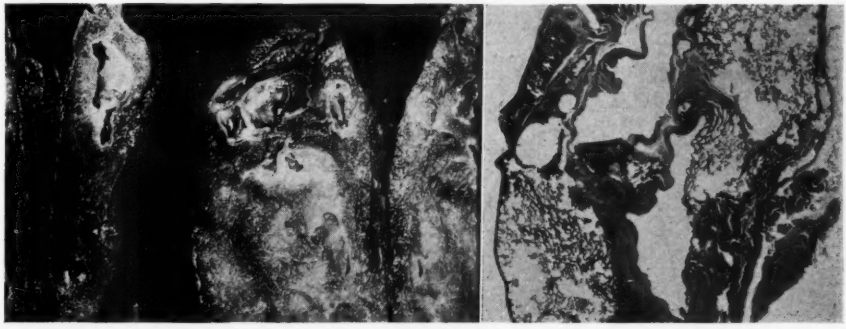

Fig. 3.—Gross and microscopic appearance of specimens removed at last operation.

Because it appeared clear that the patient was going steadily downhill, further surgery seemed necessary. Inasmuch as the lesions were located in each of the three lobes of the sole remaining (right) lung, the only possibility was to try to locate the fistulas and to ligate the efferent and afferent blood vessels, or to resect the pathologic areas, saving as much lung tissue as possible.

It was thought it would be wise to employ an oximeter during the operation, both as an aid for the anesthesiologist in evaluating the patient's condition, and as a possible help in identifying the fistulas, as one would expect an immediate rise in oxygen saturation with the compression of an area of the lung containing a fistula.

In order to test the validity of this reasoning, and to measure the degree of change which might be expected at the operation, an experiment was performed on a dog in which an end-to-end anastomosis was constructed between the pulmonary artery and pulmonary vein of the left lower lobe. A Millikan oximeter consisting of a Coleman anoxia photometer earpiece connected to a

control box built by Dr. John Perkins, Jr., from our Physiology Department, according to Millikan's compensated circuit, was made into a recording instrument by leading the output to a Brown Electronik Potentiometer. In the experiment performed on the dog, the animal was heparinized and a glass cuvette containing a film of blood 1 mm. thick was connected in series with the cut ends of the femoral artery. The oximeter earpiece was applied to this cuvette.

As indicated in Fig. 4, occlusion of the anastomosis caused a 23 per cent rise in the per cent saturation of peripheral arterial blood, whereas release of occlusion caused a corresponding fall. This experiment, then, indicated that the Millikan oximeter would indeed be sensitive enough to distinguish between the normal pulmonary arteries on the one hand and the pulmonary artery-pulmonary vein shunts known to be present in the patient's lung. The oximeter

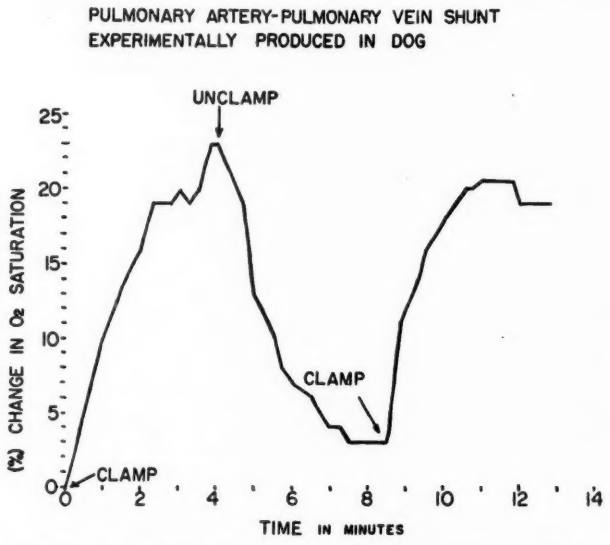

Fig. 4.—Oximeter tracing in a dog showing blood oxygen saturation with an arteriovenous fistula of the lung open and occluded.

was therefore used throughout the operation on the patient as indicated in the record (Fig. 5). The initial reading was set at 69 per cent, corresponding with the oxygen saturation found with the van Slyke method. When each one of three of the four shunts in the lung were occluded, the oximeter reading increased relatively abruptly by 7 or more per cent. At the end of the operation with still one fistula present and 100 per cent mask oxygen being administered the value was 90 per cent. Inasmuch as these three shunts consisting of cavernous hemangiomas lay on the surface of the lung and could be readily visualized, use of the oximeter in the manner described simply confirmed rather than established their location in this case. Nevertheless, we believe that in cases where shunts of this type lie deep in the lung, the method should prove valuable in locating them.

A number of additional factors were considered prior to surgery, which seemed of considerable importance in this particular case. The pulmonary vascular bed had already been reduced by half by the previous pneumonectomy. It was thought that further reduction and consequent increased resistance by the occlusion of the large arteriovenous shunts, coupled with the abnormally high viscosity (found to be 2.3 times normal as measured with an Ostvald viscosimeter) of the blood because of the compensatory polycythemia, might impose too great a strain on the right ventricle.

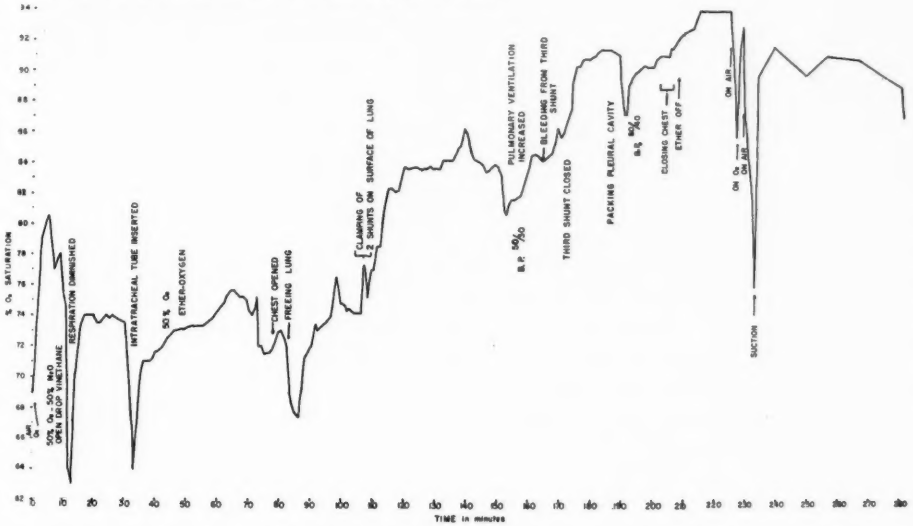

Fig. 5.—Oximeter tracing during operation; note sudden rise in oxygen saturation of the blood when shunts were occluded.

Plans were made to prevent this possible complication as follows: (1) right ventricular pressure would be measured throughout the operation in order to determine whether this pressure rose to dangerously high levels during ligation of the pulmonary shunts; (2) blood initially lost at operation would be replaced with saline, plasma or both, rather than with whole blood, in order to reduce the relative viscocity of the blood and thus minimize the rise to be expected during ligation. It was realized, however, that a fall in systemic blood pressure occurring in this patient at the time of ligation could be the result (1) of a sudden reduction in viscocity of the blood because of less hindrance by the peripheral vascular bed to the blood flow, (2) as well as of a possible reduction in right heart output resulting from the increased resistance in the pulmonary circuit following ligation of the shunts.

After these preliminary considerations, the operation was performed by one of us (W. E. A.) on Feb. 10, 1950. Under local anesthesia, a cardiac catheter was introduced in a jugular vein (as it was impossible to introduce it into an arm vein), and under fluoroscopic control placed in the right ventricle for pressure recordings (Table II). Intravenous normal saline solution was

TABLE I. BLOOD DATA. A SUMMARY OF THE CLINICAL COURSE AND LABORATORY FINDINGS IN A PATIENT WITH BILATERAL PULMONARY ARTERIOVENOUS FISTULAS

DATE	THERAPY AND COMMENTS	VITAL CAPACITY	RED BLOOD CELLS	HEMOGLOBIN (GM.)	HEMATOCRIT	ARTERIAL OXYGEN SATURATION
2/ 8/43		3,800	7.2	23.0	82.0	71.0
2/11/43	*Pneumonectomy, left*					
2/15/43			6.4	17.0	51.5	72.0
3/ 4/43	Discharged from hospital		5.4	17.5		
11/22/43	Working	2,200	5.05	15.7	54.0	85.0
5/ 4/48	Thoracoplasty		5.9	21.0		
6/ 3/49	New A-V fistula seen in right lower lobe		6.48	20.4		
10/12/49				24.0	70.0	78.0
2/ 3/50		1,100	7.19	22.0	75.0	69.0
2/10/50	*Excision of 2 and closure of one A-V fistula*					
3/ 6/50			5.6	17.0	47.0	
4/ 7/50		1,100	5.64	19.0	62.0	85.0
9/18/50			5.57	18.4		
1/ 3/51		1,400	5.35	17.4	59.0	86.0

started in both legs. Endotracheal ether-oxygen anesthesia was employed and, when the chest was opened, intermittent positive pressure was applied by assisted respiration throughout. Every fifteen minutes the hematocrit was measured. Blood loss was estimated by weighing sponges.

Operation: The right thorax was entered through the bed of the seventh rib, which was removed subperiosteally. The entire pleural space was found to be obliterated. Adhesions were freed over the right middle and lower lobes. One arteriovenous fistula was found at the surface of the lung at the lower medial aspect of the right lower lobe, and another was found at the lower lateral aspect of the right middle lobe. The fistulas were noted to pulsate, but no thrill was palpated. The two areas containing fistulas were clamped off with right angle clamps and resected. At about the time of closure of the second fistula the blood pressure dropped to 50/30. Transfusion with plasma

TABLE II. RIGHT VENTRICULAR PRESSURES DURING OPERATION, FEB. 10, 1950

TIME	SYSTOLIC MM. HG	DIASTOLIC MM. HG
9:20 A.M. Induction period	40-50	20
9:30 A.M.	35-38	20-25
9:50 A.M.	30-40	7-10
10:05 A.M.	25-40	5-15
10:10 A.M. Chest open	25-30	10
10:20 A.M.	25-30	10
10:30 A.M. Vessels exposed	25-35	10-15
10:40 A.M.	25	10-15
10:50 A.M. 1st set of vessels clamped		
10:55 A.M.	25-30	10
11:00 A.M.	30	0– –2
11:15 A.M. 2nd set of vessels clamped		
11:20 A.M.	30	–2
11:40 A.M. 3rd set of vessels clamped		
11:45 A.M.	40	0
12:00 M.	45	–2
12:25 P.M.	45	0
12:30 P.M. Chest closed		

failed to produce a satisfactory rise in systemic pressure. Since the right ventricular pressure was only 30 mm. Hg (well within normal limits) it was decided to give whole blood. The systemic blood pressure rose to 80/40 soon after this transfusion. Freeing of the adhesions over the right upper lobe was next begun. As the posterolateral aspect of this lobe was approached, a thrill could be palpated.

A third arteriovenous fistula, located in the upper lobe, was broken into and bled considerably, causing a blood loss of 300 to 400 cubic centimeters. Clamps were placed proximal to control the bleeding. This fistula was then obliterated with multiple interrupted sutures. There appeared to be a fourth fistula deep in the substance of the lower lobe, but it was felt not justified to attempt its removal, because it would have been necessary to sacrifice too much lung tissue. Two Pezzar catheters were brought through the eighth interspace, and the wound was then closed in layers. The patient's condition remained relatively good throughout the procedure.

The hematocrit which was 75 per cent just before the operation had dropped to 60 per cent at the end of the procedure.

The estimated blood loss was 2,500 c.c. Replacement consisted of 1,200 c.c. of saline, 1,500 c.c. of plasma and 1,550 c.c. of blood, given during the operation which required three hours and fifteen minutes.

It can be seen in Table II that the systolic right ventricular pressure increased after clamping the fistulas, while the diastolic went down. The high right ventricular pressure during induction must be attributed to straining of the patient. As the viscosity came down gradually during the procedure, as indicated by the decrease in hematocrit, one might have expected a drop in the abnormally high right diastolic pressure recorded at the start.

The patient's postoperative course was quite stormy for the first week. He had much difficulty raising secretions, and bronchoscopy and intratracheal aspirations were needed rather frequently. He remained quite apprehensive, but was able to be up and about most of the day in a wheel chair after the first week. At the time of discharge (four weeks after the operation) he was walking around the ward. His vital capacity at that time appeared to be less than 1,000 cubic centimeters.

At the present time (January, 1951) the patient is in fairly good condition. At rest he is not cyanotic, and is able to do some light exercise. He can walk up two flights of stairs slowly without resting, walk several miles on the level, and is much less short of breath than before operation. More than slight exercise, however, is too much for him, for he then becomes rapidly short of breath and markedly cyanotic. His blood oxygen saturation in room air is 86 per cent and goes up to 100 per cent on inhalation of 100 per cent oxygen. His red blood count is 5,350,000; hematocrit, 59; and hemoglobin, 17.4 Gm. The vital capacity has increased and is now 1,400 c.c. In general the patient feels much better than prior to surgery. However, in view of the fact that he developed more arteriovenous fistulas after one operation, his prognosis is uncertain.

DISCUSSION

It is generally accepted that the best treatment in these cases is to remove as little lung tissue as possible, since pre-existing fistulas may open up or new ones may develop following surgery and cause a recurrence of the clinical picture. In this case it was thought in 1943 that a pneumonectomy was the best treatment. It would, however, have been better to have performed a partial resection of the lung. Since the condition in most of these patients gradually gets worse, as indicated by the decreasing oxygen saturation and increasing polycythemia, surgery should always be considered. The prognosis without surgery is usually unfavorable, the cause of death being cerebral thrombosis, pulmonary bleeding, or heart failure.

SUMMARY

A case of multiple arteriovenous fistulas of both lungs, for which parts of the right lung had to be resected seven years after a left pneumonectomy, is presented. Difficulties encountered are discussed. The patient improved considerably after surgery. However, in this patient the prognosis must remain guarded.

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A USEFUL BRONCHIAL CLAMP

WALTER J. BURDETTE, PH.D., M.D.
NEW ORLEANS, LA.

A BRONCHIAL clamp* (Fig. 1) has been designed which has proved very useful in the management of the bronchus during pulmonary resection. It consists of thin blades with serriform jaws 3.5 cm. in length at right angles to a handle 20.7 cm. long containing a screw mechanism for closing the jaws. The two parts of each instrument may easily be disassembled for cleaning.

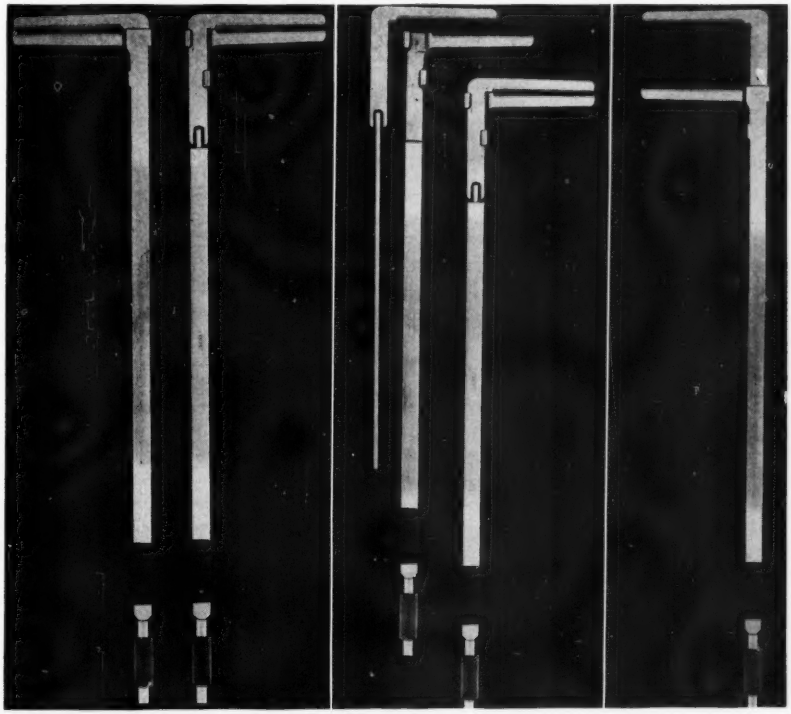

Fig. 1.—Bronchial clamp showing serriform jaws open, closed, and disassembled for cleaning.

A syringe fits the end of the handle and may be used to clean the bore. The instrument is constructed of stainless steel and is quite sturdy, although it weighs only 37 Gm. It is sterilized in oil and left with a light coating of oil when not in use.

From the Department of Surgery, Louisiana State University School of Medicine.
Received for publication August 6, 1951.
*Manufactured by Mr. B. Richter, 843 Duane Street, Glen Ellyn, Illinois.

The thin blades permit easy application, and the screw adjustment and serriform jaws prevent slipping, avoiding the necessity of crushing the tissue. The absence of ratchet handle and the construction of the shaft at right angles to the blades result in the clamp being placed at 90 degrees to the bronchus. This prevents the handle from lying in the axis of the bronchus where the distal pulmonary parenchyma interferes with proper use of the instrument. When the clamp is in place on the proximal bronchial stump it is useful in manipulating the stump as sutures are placed.

When the bronchus is closed on the proximal side without the use of a clamp, either before or after it is cut, paired clamps are not used, but a single clamp is useful in occluding the distal portion of the bronchus which is to be removed. This, of course, is desirable as early as possible to prevent contamination of the remaining tracheobronchial tree by the part to be resected. Although the instrument is primarily constructed for work with the bronchus, it has some usefulness in vascular surgery as well.

SUMMARY

A stainless steel bronchial clamp has been designed with serriform blades and screw handle which is convenient to apply with little danger of slipping and minimal damage to tissue.

GANGRENE OF THE ARM FOLLOWING USE OF THE SUBCLAVIAN ARTERY IN A PULMONOSYSTEMIC (BLALOCK) ANASTOMOSIS

WATTS R. WEBB, M.D., AND THOMAS H. BURFORD, M.D.
ST. LOUIS, MO.

THE occurrence of gangrene of an extremity following interruption of the subclavian artery incident to the performance of an anastomosis to the pulmonary artery has been an extremely rare complication. There has been only one such case previously reported,[4] in the many hundreds of anastomoses. This of course demonstrates the very efficient collateral circulation of the shoulder girdle. Very little, however, has been written about the exact patterns of this collateral. Our interest was stimulated by the following case.

CASE REPORT

B. J. B., a 1-year-old girl, entered Children's Hospital on Feb. 6, 1950, because of cyanosis since birth. The parents noted that the child had dyspnea when eating or crying, and occasional attacks of syncope. She had had frequent upper respiratory infections with slow recovery. She had gained eight pounds since birth. Because of the poor progress shown by the child while under observation through the outpatient clinic, early operative intervention was deemed necessary.

Physical examination showed a small, cyanotic, moderately well-developed infant girl with clubbing of the fingers and toes. She demonstrated marked dyspnea when crying or eating. The tonsils were enlarged and injected. The lungs were clear. The heart appeared enlarged to percussion both to the right and to the left. A faint systolic murmur and thrill were present over the precordium, with greatest intensity in the third interspace to the left of the sternum. The blood pressure was 90/50, with equal pulses in all extremities.

The laboratory data showed a normal urine, a white blood cell count of 12,000 per cubic millimeter with a normal differential, and 7.2 million red blood cells with 15.2 Gm. hemoglobin. The electrocardiogram showed sinus tachycardia and right axis deviation, and was suggestive of myocardial damage. Chest roentgenograms showed findings typical of a tetralogy, with inconspicuous vascular shadows bilaterally and a concave pulmonary conus. There was moderate right ventricular hypertrophy, and the aortic window appeared clear. The aortic arch was on the right.

The patient improved on digitalis and oxygen, and the acute tonsillitis responded to penicillin and streptomycin therapy.

Operative Findings.—On Feb. 13, 1950, a left thoracotomy was performed through a posterolateral incision with resection of the fourth rib. The aorta was found to descend on the right side, as had been thought preoperatively. Though the subclavian and pulmonic vessels were very small, it was decided to attempt an anastomosis. In order to obtain sufficient length the subclavian artery was transected distal to its first four branches, and the internal mammary, vertebral, costocervical, and thyrocervical vessels were individually ligated. An end-to-side anastomosis of the subclavian to the pulmonary artery was performed. A thrill at the end of this procedure indicated its patency.

Postoperatively the patient showed only slight improvement in color, and a murmur typical of a shunt was never identified. On the first day after operation lividity and coolness of the left forearm were noted. Because these changes might be due to thromboses, inter-

From the Department of Surgery, Washington University School of Medicine and the Chest Surgical Service, Barnes Hospital.
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CHART I. MAJOR COLLATERAL CHANNELS AFTER SIMPLE LIGATION OF THE SECOND PART OF SUBCLAVIAN ARTERY

First portion of subclavian	Transverse scapular and Transverse cervical of the thyrocervical	with	Thoraco-acromial Subscapular Circumflex scapular	to axillary
First portion of subclavian	Internal mammary Superior intercostals of the costo-cervical Aortic intercostals	with	Pectorals of thoraco-acromial Superior thoracic Lateral thoracic Subscapular Circumflex scapular Dorsal thoracic	to axillary
First portion of subclavian	Unnamed branches passing through axilla	with	Branches of the axillary	

CHART II. COLLATERAL CIRCULATION AFTER LIGATION OF THE SECOND PORTION OF SUBCLAVIAN ARTERY AND LIGATION OF THE INTERNAL MAMMARY, VERTEBRAL, THYROCERVICAL, AND COSTOCERVICAL TRUNKS

Contralateral inferior thyroid Homolateral superior thyroid	Inferior thyroid	Transverse scapular Transverse cervical	with	Thoraco-acromial Subscapular Circumflex scapular Dorsal thoracic
Homolateral carotid muscular branches Homolateral occipital Contralateral vertebral muscular branches	Ascending cervical Deep cervical	Aortic intercostals		
Inferior epigastric Aortic intercostals	Internal mammary Superior intercostals		with	Pectorals of throraco-acromial Superior thoracic Lateral thoracic Subscapular Circumflex scapular Dorsal thoracic
Aortic intercostals	Unnamed branches passing through axilla from branches of subclavian		with	Branches of the axillary

mittent injections of intravenous heparin were started. However, adequate clotting time levels could not be consistently maintained. By the third postoperative day there was demarcation of the changes at the junction of the upper and middle thirds of the forearm. On the fifth postoperative day the patient developed right facial weakness and weakness of the right arm and leg, with increased tendon reflexes on the right apparently from a cerebral thrombosis. These symptoms gradually cleared, but the left forearm proceeded to dry gangrene and mummification. The patient's cyanosis returned to its preoperative intensity indicating the

anastomosis had thrombosed. On March 23, 1950, the left forearm was amputated with primary healing of the wound. The patient was discharged three weeks later still showing cyanosis and having occasional episodes of syncope.

DISCUSSION

Universally, after division of the subclavian artery, the arm becomes pulseless, and frequently cool. This gradually improves and, while only a faint radial pulse may return, in time the arm seems to become as well developed, as strong, and as warm as its fellow member. In attempting to explain the degree of ischemia seen above we were led to consider several factors, the first of which is the collateral circulation. After simple ligation of the second part of the

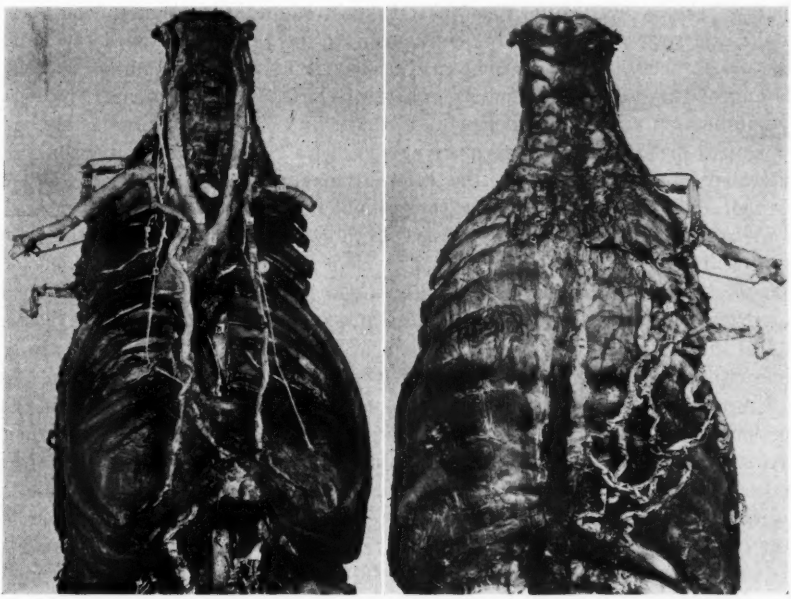

Fig. 1.—Anterior and posterior views of an injected specimen with coarctation of the aorta. This shows the prominence and multiplicity of the available intercostal and subscapular collateral pathways.

The specimen is that of a 65-year-old white man, prepared by Dr. E. E. Devereux and Dr. R. B. Stortz, from the Museum of the Department of Anatomy, Washington University School of Medicine.

subclavian the major collateral channels are as shown in Chart I. Thus, blood may leave the subclavian through the internal mammary, thyrocervical, and costocervical trunks and be efficiently shunted around the point of ligation. The vertebral contributes only a very few further collateral channels.

This is in marked contrast to the circuitous route necessitated by ligation of the subclavian in its second portion when, in addition, its four trunks must be ligated at their origin (Chart II). In our experience this has seldom been necessary, but it has been done on other occasions without ill effect. In this case all blood passing through the channels depicted in Chart I must come from

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sources more distant than the first portion of the subclavian. The major routes in this situation are shown in Chart II and Fig. 1.

Of these many sources of blood flow the most important is the intercostals, principally from the posterior and lateral branches, with their anastomoses to the subscapular and the lateral thoracic vessels. This is visually very strikingly demonstrated by the injected specimen of a case of coaretation of the aorta (Fig. 2). Although the situations are not exactly analogous, the accompanying picture displays an exaggerated form of the usual anastomotic patterns.

Lam believed the posterolateral incision was responsible for the gangrene in the case he reported. He did not, however, give full details of the site of division of the subclavian artery, so that it is not possible to adjudge all the relative factors. It would seem that the posterolateral incision in comparison would interrupt more collateral circulation of the arm than would the anterolateral approach. The posterolateral incision divides branches of the subscapular and of the descending ramus of the transverse cervical arteries, and severs communication with the posterior and lateral divisions of all intercostals below the fourth or fifth intercostal space according to the site of the incision. The anterolateral incision divides the internal mammary, the supreme thoracic, the thoracic branches of the thoraco-acromial trunk, and the anterior branches of the superior and aortic intercostals. Both types of incision divide the lateral thoracic artery with the anterolateral incision doing so at a higher level. The sum total seems to give some slight advantage to the anterolateral incision, but in view of the large number of Blalock procedures done through the posterolateral incision without difficulty even in older children and adults we are convinced that the site of incision is not too important.

A far more significant factor, it seems to us, is that of thrombosis of some portion of the collateral circulation. These individuals with their polycythemia have a well-recognized tendency to spontaneous intravascular thrombosis[8] which is accentuated postoperatively. Ligation of a mother trunk, for example, the thyrocervical, would enhance the possibility of local thrombosis with propagation into its diverging branches. That this factor played a role here is suggested by the evidence of thrombosis developing at the site of the subclavian pulmonary anastomosis and in the cerebral circulation.

Another possible factor is spasm of the arteries. The importance of this has been recognized by many workers, especially those dealing with traumatic vascular injuries, such as those incurred during war.[1, 7] The experiments of Kinmonth, Simeone, and Perlow[3] are particularly pertinent in pointing out the prompt appearance of arterial spasm after many types of mechanical trauma, such as operative manipulations. Usually the constriction is seen in only a localized segment of the traumatized vessel for a brief period of time, but it may persist for days, especially in the presence of nerve and other soft tissue injuries. Vasospasm is difficult to evaluate in any given case, and hard to recognize except by diagnostic anl therapeutic sympathetic nerve blocks. When, as in this instance, blocks have not been done, one can only speculate as to its importance.

The site of demarcation of the gangrene in this case is an interesting feature for which no exact explanation is at hand. While in the leg it is possible

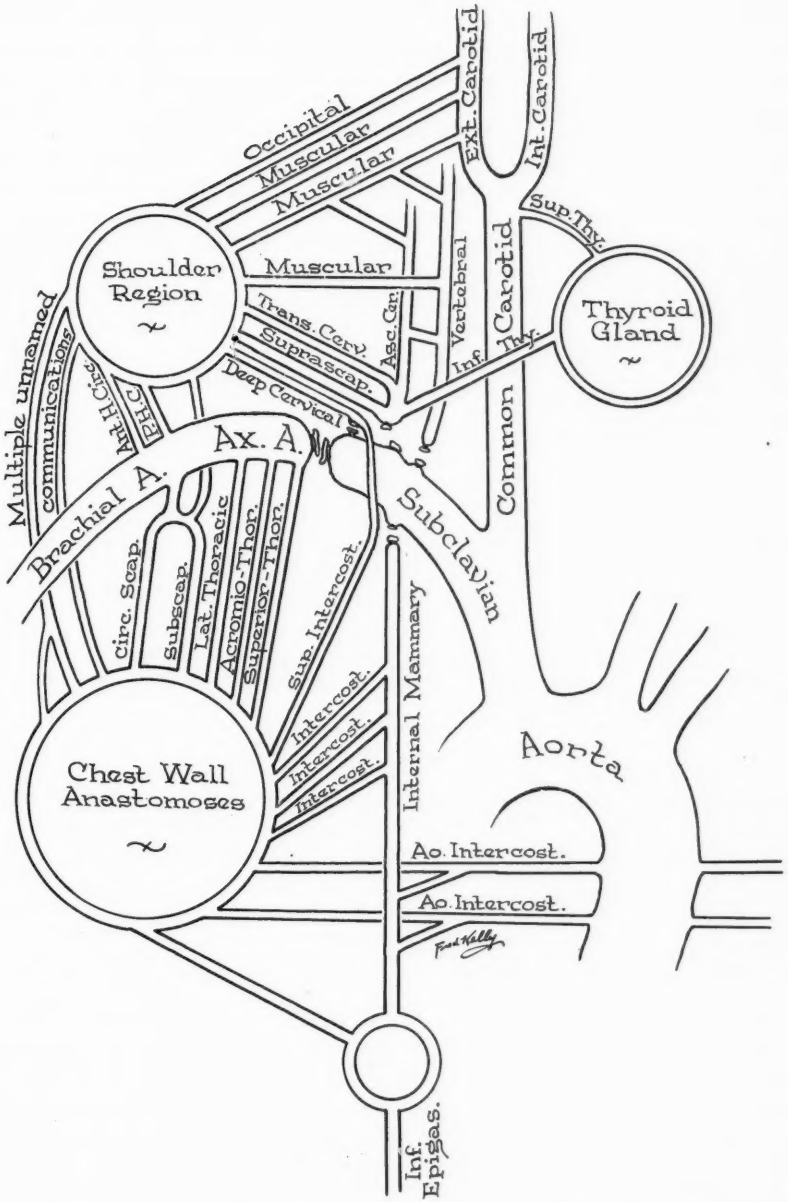

Fig. 2.—Diagram of the collateral circulation to the arm after ligation of the second portion of the subclavian artery and its branches.

to associate a given level of gangrene with arterial occlusion at a relatively definite point, this cannot be done in the arm. Since nearly all the data for gangrene developing after occlusion of the arteries of the axilla or arm have come from traumatic injuries when there have been associated injuries to the collateral circulation, they are not applicable to this problem.[2, 6] Leriche and Policard[5] found the common brachial artery proximal to the orifice of the profunda to be the only dangerous site for ligation. They report one case with subsequent gangrene of the digits of the hand and one case with atrophy and fibrosis of the upper arm and hand muscles. They state nothing, however, about the type of injury or the collateral circulation and collect thirty-one cases of ligation of the brachial artery at this point without subsequent gangrene. It is obvious that circulation to the distal parts is more seriously impaired than that of the more proximal portion of the extremity, and the demarcation must occur at some point along the gradient. The minimal vascular bed in this case undoubtedly lays in the collateral of the shoulder girdle at the sites of vasosection and thrombosis.

SUMMARY

1. A case of gangrene of the arm following use of the subclavian artery in a Blalock type anastomosis for tetralogy of Fallot in a one-year-old child is presented.

2. The collateral circulation of the arm is discussed.

3. The effects of the type of incision, of intravascular thrombosis, and of vasospasm are reviewed.

We wish to express our appreciation to Dr. Mildred Trotter and Dr. Edward W. Dempsey of the Department of Anatomy, Washington University School of Medicine, for their kind cooperation and assistance.

ADDENDUM

Since this was submitted for publication, one further case has come to our attention. F. D'Allaines in *Chirurgie Du Coeur,* Paris, 1950, Scientifique Francaise, reports the development of gangrene of the entire left arm of one patient after the subclavian artery had been anastomosed to the pulmonary artery. The operation was performed through an anterolateral incision, which we feel lends support to our view that the location of the incision is not an important factor. Details of the patient's age and of the level of transection of the subclavian artery are not given.

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FIBROMA OF THE LUNG

Case Report

Paul D. Crimm, M.D., and Frederick L. Kiechle, M.D.
Evansville, Ind.

PRIMARY benign tumors of the lung are not very frequent in occurrence. Undoubtedly, many of these take origin from the bronchus and can be considered as bronchial tumors. The larger tumors are those described usually as lung neoplasms, while the smaller ones are regarded as bronchial neoplasms. Benign tumors[1] include papilloma, fibroma, lipoma, myoma, chondroma, osteoma, and adenoma, which is considered by Graham and Womack[2] to be potentially malignant.

Among cases of fibroma of lung previously reported are those of Staffieri and associates,[3] and of Houyez.[4] Lindgren[5] reports that fibromas represent 9 per cent of the bronchial tumors reviewed by him. Lyssunkin[6] reports a fibroma of the lung which underwent malignant change to a xanthomatous fibrosarcoma. Lenk[7] mentions that sarcomas of the lung are quite rare, comprising an estimated 0.009 to 0.02 per cent of all autopsies.

Benign lung tumors may give no indication of their presence for years, until they attain such size that they cause pain, circulatory embarrassment, dyspnea, or pulmonary osteo-arthropathy. Blockade of bronchi, either by compression or tumor growth, gives rise to cough and inadequate drainage. These symptoms of obstruction often are diagnosed as bronchitis or pneumonia.

CASE REPORT

This patient was a white man, aged 48 years, occupation laborer. He complained of persistent cough and pain in the right chest, which was present four weeks prior to consulting his local physician. Pain was of sharp, migratory, and intermittent character, beginning just inferior to the left costal border and passing in a narrow band up the fifth left interspace and then crossing to right chest at the same level. Cough, slightly productive from the onset, was first noticed about September, 1949. This cough appeared when he was reclining, and very seldom occurred in the sitting posture. Hemoptysis was absent. Right-sided chest pain was more of an aching character. There was a fifteen pound weight loss over a two-month period. No joint pains were noted. Past history was noncontributory. Family history revealed no evidence of tuberculous infection, nor of neoplastic disease.

Physical examination revealed the following positive findings: Nasal septum was deviated slightly to the right, but without obstruction. Thorax was asymmetrical, with respiratory movements slightly limited on the left side. Dullness and absence of breath sounds existed in the left base.

Laboratory findings were as follows: Urinary findings were essentially negative. WBC 10,300; basophils 3 per cent, eosinophils 2 per cent, juveniles 1 per cent, stabs 3 per cent, segmenters 71 per cent, lymphocytes 20 per cent. Sedimentation rate was 28 mm. (Cutler method). RBC 3,110,000, with 60 per cent Hb. (Sahli). Blood type "O." Bleeding time was four minutes, and clotting time was one and one-half minutes. Postoperative blood count

From Boehne Tuberculosis Hospital.
Received for publication Aug. 29, 1951.

was: WBC 8,900; eosinophils 2 per cent, stabs 2 per cent, segmenters 73 per cent, lymphocytes 23 per cent; RBC 2,960,000, Hb. 54 per cent. Following transfusions, counts rose to RBC 3,280,000, Hb. 60 per cent; and RBC 4,170,000, Hb. 74 per cent.

Bronchogram (Fig. 1) in October, 1949, showed atelectasis in the left lower lobe and demonstrated obstruction of the lower bronchus, presumably by a tumor mass. The tumor was visualized at the time of bronchoscopy and biopsy obtained showed architecture of benign fibroma.

Operative Report: Tumor mass comprised most of the lower lobe, which was firmly adherent laterally to the chest wall. The inferior and medial adhesions were separated readily. The upper lobe was fixed by adhesions. The lower lobe and tumor were removed by the usual individual ligation technique. No sign of metastasis or extension of tumor within the operative field was observed. A lymph node near the hilus contained necrotic fluid. Several other slightly enlarged lymph nodes were removed. Recovery was uneventful. Patient was discharged on the sixteenth postoperative day with remaining lobe expanded.

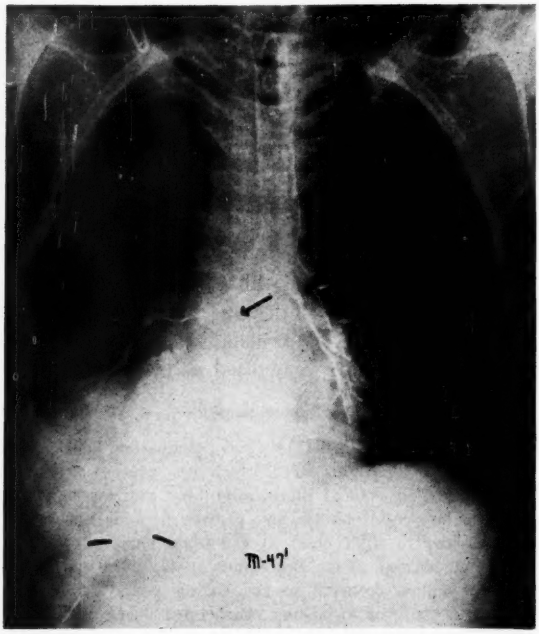

Fig. 1.—Bronchogram shows blockade of left lower bronchus and increased density throughout the lower lobe.

Gross Pathology: The tumor occupied more than half of the lower lobe volume. The weight of the lower lobe with the tumor was 740 grams. Hemisection (Fig. 2) demonstrated two spherical tumors, the one much larger and of firm rubbery consistency and suggestion of whorled pattern, with slightly pinkish-yellow color and areas of white and slightly softened degeneration; the other of smaller size, equally firm rubbery consistency, but with white glistening surface. Cut surfaces bulged. Extensions of tumor tissue were seen to fill three major bronchi, and to cross a bifurcation in such a manner as to suggest the arrangement of a staghorn calculus of the kidney pelvis. There was no evidence of invasive character, and the tumor appeared to be partially encapsulated, and was well demarcated from surrounding tissues.

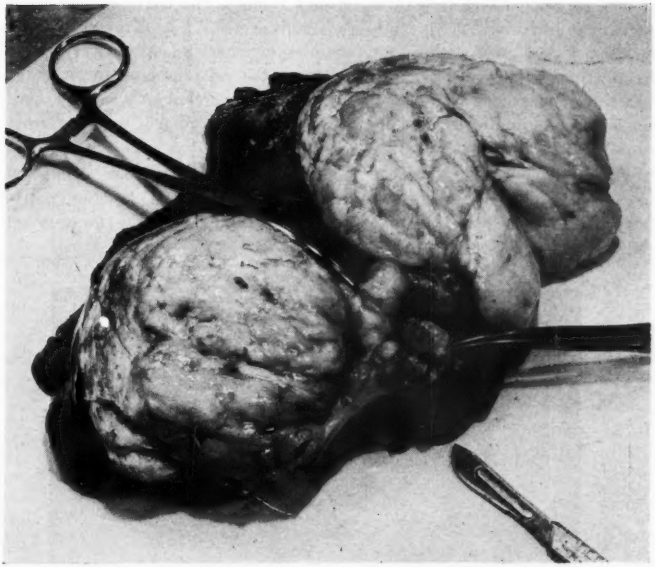

Fig. 2.—Hemisection of lower lobe shows character of tumor mass with extension into large bronchi.

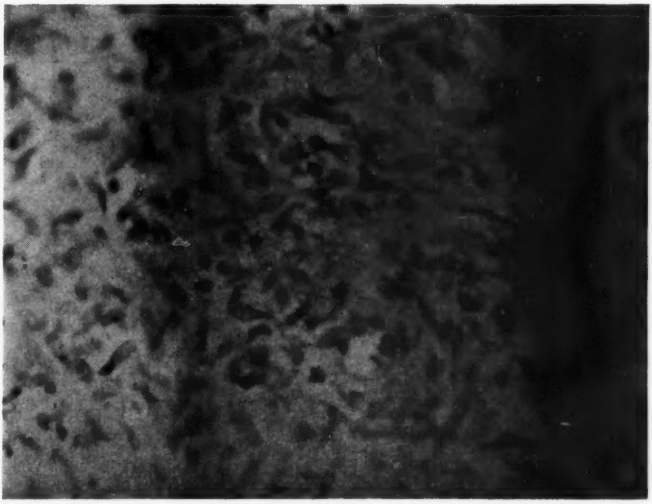

Fig. 3.—Photomicrograph (×530) showing spindle shaped cells without specific arrangement, and of low activity.

Microscopic Pathology: (See Fig. 3) There were a large number of spindle-shaped cells lying in a rather dense pink staining stroma. The nuclei were only moderately staining. They were rather uniform. They contained small nucleoli. A rare mitosis was seen. In some areas there was a great deal of pink-staining stroma with only a very few cells. There was no architectural arrangement. In other areas the cells were more closely packed. All of the areas sectioned showed the same picture, which was that of very low activity. These sections did not show the whorled bundles nor the bluish staining of a neurofibroma. Sections of two lymph nodes showed no tumor cells.

Subsequent Course: This patient has remained well eighteen months and leads a normal life, with no evidence of recurrence or metastasis. Fig. 4 shows radiograph taken eighteen months after surgery. Lung is re-expanded except in the lower third where the pleurae are thickened.

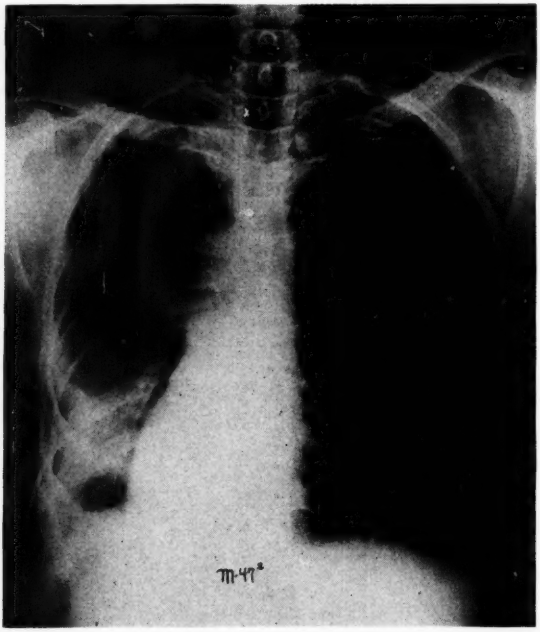

Fig. 4.—Radiograph shows left upper lobe well expanded, except in lower third where the pleurae are thickened.

COMMENT

This tumor suggested that it originated from connective tissue of the bronchial wall, due to its physical arrangement and cellular picture. However, because of its size and extension into the lung by compression, the tumor was considered a fibroma of the lung.

SUMMARY

1. A case of benign fibroma of lung is presented.

2. Eighteen months after removal of tumor, and the left lower lobe, there has been no recurrence.

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Constitution and By-Laws of the American Association for Thoracic Surgery

CONSTITUTION OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

(Amended April 17, 1951)

ARTICLE I. NAME

SECTION 1.—This Association shall be known as the American Association for Thoracic Surgery.

ARTICLE II. OBJECT

SECTION 1.—The object of the Association shall be to encourage and stimulate investigation and study that will increase the knowledge of intrathoracic physiology, pathology, and therapy, to correlate such knowledge and disseminate it.

SECTION 2.*—To attain this object, the Association shall hold at least one scientific meeting every year in which free discussion shall be featured; shall conduct a Journal for the publication of the papers presented at this meeting, and other acceptable articles; and shall undertake such other activities as the Council or the Association as a whole may decide.

ARTICLE III.†

ARTICLE IV. MEMBERSHIP

SECTION 1.—There shall be four classes of members: Active, Associate, Senior, and Honorary. Admission to membership in the Association shall be by election. *There shall be no numerical limits on any class of membership. Only Active and Senior members shall have the privilege of voting or holding elective office.*‡

SECTION 2.—Election to all classes of membership shall *be for life, subject to the provisions of Section 3, following. (Section 3 deals with resignation and/or expulsion for cause.)*§

SECTION 3.—Membership may be voluntarily terminated at any time by members in good standing. The Council, acting as a Board of Censors, may recommend the expulsion of a member on the grounds of moral or professional

*As amended in 1950.

†Amendment to delete this article passed in 1936. The article was concerned with membership in the Congress of American Physicians and Surgeons which ceased to exist.

‡Amendment passed, 1948.

§Amendment passed, first reading 1939.

delinquency, and submit his name, together with the grounds of complaint, to the Association as a whole at any of the regularly convened meetings, after giving the member so accused ample opportunity to appear in his own behalf.

Article V. Officers and Government

SECTION 1.—The officers of the Association shall be a President, a Vice-President, a Secretary, a Treasurer, an Editor, and five Councilors. These ten officers and councilors shall be the governing body of the Association, and shall have full power to act on all matters, except as follows:

1. They may not alter the initiation fees or annual dues, nor levy any general assessments against the membership, except that they may, in individual cases, remit annual dues or assessments.

2. They may in no wise change the Constitution or By-Laws.

3. They may neither elect new members nor alter the status of existing members, other than to apply the provisions of Article IV, Section 2.

4. They may not deplete the principal of the Endowment Fund.

SECTION 2.—Officers and Councilors shall be elected at the annual meeting of the Association, *and shall take office upon conclusion of the meeting.** The President and the Vice-President shall be elected for a one-year term of office and neither may be re-elected to succeed himself in the same office. The Secretary, the Treasurer, and the Editor shall be elected for a one-year term of office, and any or all may be re-elected indefinitely. The outgoing President shall automatically become a Councilor for a one-year term of office. The other four Councilors shall be elected, one each year, for a four-year term of office, but no Councilor may be re-elected to succeed himself.

SECTION 3.—Vacancies occurring among the officers and councilors during the year shall be temporarily filled by action of the Council, subject to approval of the Association at the next regularly convened meeting.

Article VI. Committees

SECTION 1.—At the opening session of the annual meeting there shall be elected, after nomination from the floor of the Association, a Nominating Committee of three. This Committee shall prepare a slate of nominees for officers and councilors and shall present their report at the executive session of the Association.

SECTION 2.—The Council is empowered to appoint a Membership Committee, an Auditing Committee, a Program Committee, a Necrology Committee, and such other committees as may in its opinion be necessary. All such committees shall render their report at the executive session of the Association.

SECTION 3.—The Editor is empowered to appoint an Editorial Board, subject only to the approval of the Council.

SECTION 4.—The Association as a whole may authorize the Council to appoint Scientific or Research Committees for the purpose of investigating thoracic

*Amendment passed, first reading 1939.

problems and may further authorize the Council to support financially such committees to a limited degree. In appointing such committees, the Council shall be governed by the provisions of the By-Laws.

ARTICLE VII. FINANCES

SECTION 1.—*The fiscal year of the Association shall run from the beginning of one annual meeting to the beginning of the next annual meeting.** The books of the Association shall be kept and audited on this basis.

SECTION 2.—Members shall contribute to the financial maintenance of the Association through the medium of initiation fees, annual dues, and special assessments. The amount of the annual dues and the initiation fees shall be determined by the By-Laws.

If, at the end of any fiscal year, there be a deficit in the current funds of the Association, the Council may send out notices to that effect and invite Active Members to contribute the necessary amount so that no deficit be carried over from one fiscal year to another. The Association may, in any regularly convened meeting, vote a special assessment for any purpose *consistent with the objects of the Association (Article II),* and such special assessment shall become an obligatory charge against the classes of members affected thereby.†

SECTION 3.—To meet the current expenses of the Association, there shall be available all revenue derived from annual dues, special assessments, and income from Endowment Fund, subject to the provisions of Section 4, following. Funds derived from the payment of initiation fees shall not be available for current expenses.

SECTION 4.‡—All funds derived from the payment of initiation fees shall be placed in a special fund, to be invested and reinvested in legal securities, to be held intact and to be known as the Endowment Fund. The Council is responsible for the proper management of the Endowment Fund, and may divert any surplus in the current funds of the Association into this fund, but may not withdraw any of the principal of the Endowment Fund except in accordance with the provisions of Section 6, following.

SECTION 5.‡—The income from the Endowment Fund shall be expended as the Council directs.

SECTION 6.‡—The principal of the Endowment Fund may be withdrawn, in whole or in part, under the following conditions only: The amount of principal to be withdrawn shall have been approved by the Council; it shall have been approved by a majority of the members present and voting at a regularly convened annual meeting; it shall have been tabled for one year; it shall have been finally passed by a three-fourths vote of the members present and voting at the next regularly convened annual meeting.

SECTION 7.—In the event of the dissolution of the Association, the Endowment Fund shall be distributed among national institutions of the United States and Canada in a proportion equal to the then existing ratio between the numbers of citizens of the two nations who are members of the Association.

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*Amendment passed, first reading 1939.
†As amended in 1950.
‡Final action taken in 1940.

Article VIII. Meetings

SECTION 1.—The time, place, duration, and procedure of the annual meeting of the Association shall be determined by the Council, and the provisions of the By-Laws.

SECTION 2.—A special meeting of the Association may be called on one month's notice on the written request of fifteen members. The specific purposes of the meeting must be stated in the request and in the official call for the meeting.

SECTION 3.—The annual meeting of the Council shall be held at or near the close of the fiscal year.

Article IX. Amendments

SECTION 1.—This Constitution shall in no wise be changed except by a three-fourths vote of the members present at an annual meeting, and further provided that the proposed alteration or amendment shall have been moved and seconded at a previous annual meeting, and that printed copies of the suggested alteration or amendment shall have been circulated among the members, and that the members shall have been specifically advised that such alteration or amendment will be voted upon.

BY-LAWS

Article I.

SECTION 1.—These By-Laws shall merely interpret the Constitution and specifically apply its principles. They shall set forth no principles not included in the Constitution.

Article II.

SECTION 1.*—All papers read before the Association shall become the property of the Association. Authors shall leave original copies of their manuscripts with the Editor *or Reporter,* at the time of presentation, for publication in the official journal.

SECTION 2.—When the number of papers makes it desirable, the Council may require authors to present their papers in abstract, and may set a time limit on discussions.

SECTION 3.*—Members are urged to cooperate with *all* Scientific Committees of the Association.

SECTION 4.†—Attendance at Annual Meetings and participation in the scientific programs shall be optional for all Honorary and Senior Members, but it shall be expected from all Active and Associate Members.

SECTION 5.‡—While the scientific session of the annual meeting is held primarily for the benefit of the members of the Association, it may be thrown open to nonmembers who are able to submit satisfactory credentials, who register

*As amended in 1950.
†Amended by addition of Sec. 4, 1946.
‡Amendment passed, 1948.

in a specified manner, and who pay such registration fee as may be determined and published by the Council from year to year. Such registered guests shall have the privilege of the floor in discussing papers if time permits.

ARTICLE IV.

SECTION 1.—Candidates for membership in this Association must be formally nominated and seconded, in an approved manner, by not less than three Active or Senior Members. Such nomination must have been in the hands of the Membership Committee for not less than four months, and the name of the candidate must have been distributed to the Association as a whole before final action may be taken on any new candidate for election to Active or Associate Membership. Provided the foregoing requirements have been met, and the candidates have been approved by the Membership Committee and by the Council, their names shall be presented to the Association at a regularly convened annual meeting for final action. A three-fourths vote of those present and voting shall be required to elect. Any candidate for membership in this Association who has failed of election for two successive years shall automatically cease to be a candidate and may not be renominated until after a lapse of three years.

SECTION 2.*—*There shall be no numerical limit on Active Membership.* The candidate, to be eligible, must be a citizen of the United States of America or of Canada, *unless in unusual cases this citizenship requirement shall have been waived by the Council. The candidate shall have achieved distinction in the thoracic field, or shall have made a meritorious contribution to knowledge pertaining to thoracic disease or its surgical treatment. Under usual circumstances, Active Members shall be elected from the Associate Members who have satisfied all requirements for Active Membership. Under unusual circumstances, Active Membership may be awarded to new candidates of outstanding distinction.*

SECTION 3.*—*There shall be no numerical limit on Associate Membership. The candidate, to be eligible, may be a citizen of any country. All candidates for Associate Membership shall be engaged actively in the practice of clinical medicine, or in teaching, or investigative work in the basic sciences underlying clinical practice, and all shall have demonstrated an active interest in thoracic disease. In the case of those who are engaged in the independent practice of thoracic surgery, it shall be required that they present evidence of sound basic training in general as well as thoracic surgery. Younger men, still in training, who have shown an interest in the thoracic field, and who are recommended by their preceptors for the excellence of their work, may be elected to Associate Membership. Clinicians of outstanding ability, whose interest is limited to a small fraction of the entire thoracic field, may be elected to Associate Membership.*

SECTION 4.—The number of Senior Members shall be unlimited. The candidate, to be eligible, must have been an Active Member of the Association for not less than ten years or, having been an active Member, have passed the age of sixty years, or become incapacitated by illness.

SECTION 5.*—*Honorary Membership shall be reserved for such distinquished persons as may be deemed worthy of this honor by the Council with concurrence of the Association.*

*Amendment passed, 1948.

SECTION 6.*—The report of the Membership Committee shall be rendered at the annual Executive Session of the Association. Candidates shall be presented in groups in the following order: *Candidates for Honorary Membership; retirement of Active Members to Senior Membership; candidates for Active Membership; candidates for Associate Membership.*

SECTION 7.—The Council shall recommend that any member whose dues are in arrears for two years, or who has been absent, without sufficient excuse, from *three*† consecutive annual meetings, shall have his membership terminated.

ARTICLE V.

SECTION 1.—The President of the Association shall perform all duties customarily pertaining to the office of President. He shall not only preside at all meetings of the Association, but also at all meetings of the Council. The President shall be elected from the Active Members of the Association.

SECTION 2.—The Vice-President of the Association shall perform all duties customarily pertaining to the office of the Vice-President, not only as to the Association, but also as to the Council. The Vice-President shall be elected from the Active Members of the Association.

SECTION 3.—The Secretary of the Association shall perform all duties customarily pertaining to the office of Secretary. He shall serve not only as Secretary of the Association but also as Secretary of the Council. The Secretary shall be elected from the Active Members of the Association.

SECTION 4.—The Treasurer of the Association shall perform all duties pertaining to the office of Treasurer. He shall not only serve as Treasurer of the Association but shall also serve as custodian of the Endowment Fund. The Treasurer shall be elected from the Active Members of the Association.

SECTION 5.‡—The Editor of the Association shall be the Editor of the official Journal and shall, ex officio, be the Chairman of the Editorial Board. The Editor shall be elected from the Active or Senior Members of the Association.

SECTION 6.—The Councilors of the Association shall hold office as specified in the Constitution. They may be elected from either the Active Members or the Senior Members of the Association.

SECTION 7.—In the event of a vacancy occurring in the office of President, the Council shall advance the Vice-President to the Presidency and appoint a new Vice-President under the Provisions of Article V, Section 3, of the Constitution.

ARTICLE VI.

SECTION 1.—The Nominating Committee shall consist of three Active or Senior Members elected in accordance with the provisions of Article VI, Section 1, of the Constitution. The Council shall instruct the Committee as to the vacancies which are to be filled by election.

SECTION 2.—The Membership Committee shall consist of five Active or Senior Members appointed in accordance with the provisions of Article VI, Section 2,

*Amendment passed, 1948.
†Amended in 1946.
‡As amended in April, 1950.

of the Constitution. The Council may appoint not more than one of its own members to serve on this Committee. The duties of the Membership Committee are to investigate all candidates for membership in the Association and to report their findings as expeditiously as possible to the Council through the Secretary of the Association. This Committee is also charged with searching the literature of this and other countries to the end that proper candidates may be presented to the Association for consideration. Appointment to this Committee shall be for a period of one year, and not more than three of the members may be reappointed to succeed themselves. *This Committee is also charged with maintaining a record of membership attendance and participation in the scientific programs and reporting to the affected members and to the Council any deviations from the requirement of Article II, Section 4, of these By-Laws.**

SECTION 3.—The Auditing Committee shall consist of three Active or Senior Members appointed in accordance with the provisions of Article VI, Section 2, of the Constitution. None of these may be selected from the officers or councilors of the Association. Their duty shall be to audit the accounts of the Association at the end of each fiscal year and render their report to the Council of the Association through the Secretary. Appointments to this Committee shall be made for a one-year term. Not more than two members may be reappointed to succeed themselves.

SECTION 4.—The Program Committee shall consist of five members: The President of the Association, the Secretary of the Association, the Editor of the Association, and two members at large, one of whom shall be resident at or near the place of annual meeting. The duties of this Committee shall be to arrange, in conformity with instructions from the Council, the scientific program for the annual meeting.

SECTION 6.—The Editorial Board shall be appointed by the Editor, subject only to the approval of the Council. The Editor shall be, ex officio, the chairman of this board and shall be privileged to appoint and idefinitely reappoint such members of the Association, regardless of class of membership, and such nonmembers of the Association as in his opinion may be best calculated to meet the editorial requirements of the Association.

SECTION 7.—When Scientific or Research Committees are authorized by the Association, the Council shall appoint the Chairmen of these Committees, with power to organize their committees in any way best calculated to accomplish the desired object, subject only to the approval of the Council. Financial aid rendered to such Committees shall not exceed such annual or special appropriations as may be specificially voted for such purposes by the Association as a whole.

ARTICLE VII.

SECTION 1.—Honorary Members of the Association are exempt from all initiation fees, dues, and assessments.

SECTION 2.—Annual dues for Active Members shall be $25.00.

SECTION 3.—Annual dues for Associate Members shall be $20.00.

*Amended by addition, 1946.

SECTION 4.*—Senior Members are exempt from dues.

SECTION 5.—Initiation fee for those elected directly to Active Membership shall be $15.00.

SECTION 6.—Initiation fee for those elected to Associate Membership shall be $10.00. If and when an Associate Member is elected to Active Membership, he shall pay an additional $5.00 initiation fee.

SECTION 7.†

SECTION 8.—Income from the Endowment Fund shall be expended as the Council directs.

SECTION 9.—Associate and Active Members must subscribe to THE JOURNAL OF THORACIC SURGERY to retain their membership status.

SECTION 10.‡—Senior Members may retain their membership status without the payment of annual dues and subscription to THE JOURNAL OF THORACIC SURGERY is optional.

(Note.—Bills for membership dues and for subscriptions to THE JOURNAL OF THORACIC SURGERY WILL BE MAILED TO MEMBERS BY THE TREASURER AFTER THE ANNUAL MEETING.)

ARTICLE VIII.

SECTION 1.—When the Association convenes for its annual meeting, it shall immediately go into executive session, but the business at this session shall be limited to:

1. Election of Nominating Committee.
2. Appointment of necessary committees.
3. Miscellaneous business of an urgent nature.

SECTION 2.—The annual executive session of the Association shall be held at the opening of the afternoon session of the second day of the meeting. The order of business shall be:

1. Reading of the minutes of the preceding meetings of the Association and Council.
2. Report of the Treasurer for the last fiscal year.
3. Report of the Auditing Committee.
4. Report of the Treasurer for the current year to date.
5. Report of the Necrology Committee.
6. Report of the Program Committee.
7. Action on amendments to the Constitution and By-Laws.
8. Action on recommendations emanating from the Council.
9. Unfinished Business.
10. New Business.
11. Report of the Membership Committee.
12. Election of new members.
13. Report of the Nominating Committee.
14. Election of officers.

*Amendment passed in 1944.
†Section 7 deleted in 1950.
‡Amendment passed in 1944.

SECTION 3.—At the annual meeting of the Council the order of business shall be:

1. Reading of minutes.
2. Treasurer's report.
3. Appointment of committees.
4. Determination of instructions to be given to Auditing, Membership, Necrology, and other committees except Program Committee.
5. Determination of details in connection with the annual meeting.
6. Appointment and instructions to the Program Committee.
7. Unfinished Business.
8. New Business.

SECTION 4.—There shall be an annual meeting of the Council.

ARTICLE X.

SECTION 1.—These By-Laws shall in no wise be changed except by a two-thirds vote of the members present at the annual meeting or a properly convened meeting of the Association, and further provided that the proposed action or amendment shall have been moved and seconded by not less than three of the members in a properly convened annual or special meeting of the Association.

SECTION 2.—These By-Laws may be suspended in whole or in part for a period of not more than twelve hours by a unanimous vote of those present at any regularly convened meeting of the Association.